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ARMY CONCEPT TEAM IN VIETNAM
APO SAN FRANCISCO 96384

DEPARTMENT OF THE ARMY
ARMY CONCEPT TEAM IN VIETNAM
APO San Francisco 96384

WATER SUPPLY
IN THE
REPUBLIC OF VIETNAM

DEPARTMENT OF THE ARMY
ARMY CONCEPT TEAM IN VIETNAM
APO San Francisco 96384

AVIB-LED

SUBJECT: Final Report - Water Supply in the Republic of Vietnam (ACL-22F) (U)

TO: See distribution list to inclosed report

1. The inclosed report, subject as above, is forwarded for information and retention.

2. The findings, conclusions, and recommendations of the report are based solely on data generated through the Army Concept Team in Vietnam and are not to be considered as Department of the Army doctrine until incorporated in official documents.

FOR THE COMMANDER:

1 Incl
as

F. A. KLEIN
CPT, AGC
Adjutant

AVHGC-DST 1st Ind

SUBJECT: Final Report - Water Supply in the Republic of Vietnam (ACTIV Project ACL-22F)

HEADQUARTERS, UNITED STATES ARMY VIETNAM, APO San Francisco 96375

TO: Commander in Chief, United States Army, Pacific, ATTN: GPOP-DT, APO 96558

1. ACTIV final report, subject as above, has been reviewed by this headquarters. Concur in the conclusions and recommendations with the following exception:

Section III, paragraph D2e, page 55. The current command policy precludes assignment of additional personnel to operate base camps.

2. Subject report is forwarded for comment or approval. It should be noted that considerable progress in providing potable water supplies in Vietnam has been made by USARV units in the seven months that have elapsed since the data was collected.

a. A draft revision of USARV Regulation 40-45, "Water Supply", is being staffed and will be submitted for approval and publication by 15 January 1968. The proposed revision will change USARV policy on the following points raised by subject report:

(1) Water quality criteria consistent with SOLOG 125 will be specified and will be coordinated with HQ MACV (Section II, paragraph A2a, page 8).

(2) Greater emphasis will be placed on individual water discipline and on various suitable methods of emergency water treatment when CE-produced supplies are not available (Section II, paragraph B1, page 10).

(3) Instructions for the use of iodine tablets will be identical with those which will appear on bottles of the next procurement of this item. These instructions have been coordinated with USARPAC Surgeon and The Surgeon General (Section II, paragraph B1e), f), pages 12 and 14).

(4) Greater emphasis will be placed on operator competence and familiarity with technical manuals for operation of field water treatment equipment (Section II, paragraph B3f, pages 21 and 22).

(5) The details of medical procedures for surveillance of water quality will be more clearly stated. A Water Point Inspection Report (DA Form 1715-R) will be required to be completed by medical inspectors of field water points (Section II, paragraph B4a, page 24).

(6) The policy on free available chlorine residuals will be restated to eliminate ambiguity (Section II, paragraph C1c, pages 31 and 32).

(7) Testing of chlorine residuals in drinking water using the specially developed 2ppm plastic tube comparator will be specified at points of consumption (Section II, paragraph C1c(3)(b), pages 33 - 35).

(8) The use of metal POL containers for potable water storage will be permitted only in emergencies and only after proper cleansing in accordance with paragraph 43, TM 5-700. Potable water storage in collapsible rubber drums not specifically intended for this purpose and in any former container of insecticides or other hazardous materials will be prohibited (Section II, paragraphs D2 - 5, pages 39 - 46).

b. USARV Regulation 40-20, "Sanitary Standards for the Manufacture and Handling of Ice", has been published in English and Vietnamese. This regulation provides, in part, for stricter controls on handling potable ice (Section II, paragraph B5, pages 25 - 29).

c. The non-standard water analysis kit used in this command was evaluated by the 20th Preventive Medicine Unit(S)(F). The evaluation report was submitted to CINCUSARPAC as an inclosure to letter, AVHSU-PM, HQ USARV, dated 7 July 1967, subject: Request for Standardization of Equipment, which recommended that the kit not be standardized and that appropriate RDT&E be undertaken to produce a suitable kit (Section II, paragraph C1b, page 31).

d. USARV Circular 40-2, "Measurement of Free Available Chlorine and pH in Water", was published 17 October 1967 to provide readily available technical instructions and equipment supply information to water point operators, water supply supervisors, and AMEDS personnel performing water quality surveillance (Section II, paragraph C1c, pages 31 - 35).

e. Supply problems associated with providing expendable items for use with the Water Testing Kit, Bacteriological (FSN 6665-682-4765) are being resolved by increasing medical depot requisitioning objectives for these items and by improving accuracy of consumption rate estimates (Section II, paragraph C2b, page 35).

3. Action is urgently needed at DA on the below listed recommendations in Section III:

AVHGC-DST 27 DEC 1967

SUBJECT: Final Report - Water Supply in the Republic of Vietnam (ACTIV Project ACL-22F)

a. Improve the packaging of iodine purification tablets (paragraph B2a, page 52).

b. Improve water supply operator competence and career field (paragraphs B2(e), (f), page 53).

c. Authorize additional 400-gallon 1½ Ton water trailers (paragraph D2d, page 55).

FOR THE COMMANDER:

for Joseph J Minnella

1 Incl
as

JOHN V. GETCHELL
Captain, AGC
Assistant Adjutant General

ARMY CONCEPT TEAM IN VIETNAM
APO San Francisco 96384

FINAL REPORT

WATER SUPPLY IN THE REPUBLIC OF VIETNAM

ACTIV Project No. ACL-22F

6 DEC 1967

Approved:

WILLIAM G. SULLIVAN
Colonel, Infantry
Commanding

AUTHORITY

Letter, ACTIV-LCD (20 Oct 1966) 1st IND, USARPAC (30 Nov 1966), 2d IND, USACDC (8 Dec 1966), subject: Water Supply in Republic of Vietnam.

ACKNOWLEDGMENTS

The Army Concept Team in Vietnam is indebted to the following for their help in the evaluation:

1st Cavalry Division (AM)
1st Infantry Division
4th Infantry Division
25th Infantry Division
1st Brigade, 101st Airborne Division
173rd Airborne Brigade
196th Light Infantry Brigade
11th Armored Cavalry Regiment
5th Special Forces Group
1st Logistical Command
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FRONTISPIECE. Water in the canteen goes everywhere with the soldier in the firld.

SUMMARY

This project was conducted to evaluate water supply and procedures, to determine water requirements and sources and the adequacy of containers and storage facilities, and to evaluate the purification and delivery means to meet the requirements of supporting US Army troops in the Republic of Vietnam (RVN).

During the data collection phase US Army units from the II, III, and IV Army of the Republic of Vietnam (ARVN) Corps areas were visited by the evaluation team. Data were collected through standard checklists, structured interviews, search of records and forms, and observations of units in an operational environment.

United States Army troops have adequate potable water which is produced primarily from ground raw water sources. The individual soldier consumes about 5 quarts of liquids per day and normally begins a combat optration carrying 4 to 6 quarts of water. Daily resupply of water by helicopter is routine. Individual canteens are adequate but could be improved by changing certain design features. Storage and distribution equipment (400-gallon water trailers and 1000-gallon water tank trucks) used by troop units are inadequate to support the type of mobile operations being conducted in RVN. Military water production and well drilling personnel lack adequate training and experience and have poor career opportunities, which degrades the overall water production program. Water production equipment (i.e.,the Erdlator) is adequate when available in a size appropriate for supporting a specific mission.

Drinking water for troops is not a major problem in Vietnam even thought certain areas require improvement. Standard treatment equipment is considered adequate when maintained properly. Medical and engineer personnel need improved test equipment in order to perform the necessary test and evaluations of new raw water sources.

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I. INTRODUCTION

A. PURPOSE

The purpose of this project was to evaluate the doctrine, concepts, procedures, and materiel for supplying potable water to US Army tactical units within the Republic of Vietnam (RVN).

B. BACKGROUND

Water supply within RVN is a complex problem, which has been magnified by the buildup of combat forces. Preliminary investigation revealed that water supply procedures differ among major tactical units (divisions and separate brigades), and occasionally within the same major tactical unit, for support within both the tactical area of responsibility (TAOR) and area of operations (AO). These variations are caused by different concepts for water supply, environmental conditions, materiel availability, and tactical concepts of operation. For example, on search and destroy missions, some units require individual soldiers to carry sufficient ammunition, food, clothing, water and other personal equipment to sustain him for the duration of the operation, usually 2 to 3 days. Other units rely on resupply by helicopter at predetermined points or times. For larger operations (brigade or larger), the 1st Logistical Command may establish forward supply bases. Water points are normally provided within these bases.

Realizing that different procedures to supply water may be necessary because of differencesin operational environment, transportation requirements and availability, purification means and devices, materiel availability, and tactical concept of operation, the Army Concept Team in Vietnam (ACTIV) was tasked to determine if current doctrine provides sufficent guidance and if materials are available in the types and quantities required to support the supply of water in RVN.

C. DEFINITION OF TERMS

1. Contaminated Water- Water that contains potential disease producing organisms.

2. Diatomite Water Purification Set — Batch-type water treatment using flocculation, sedimentation, filtration, and chlorination. This equipment is now classified as STD-C and is being replaced by the continuous flow equipment (Erdlator).

3. Disk Comparator - Equipment for colorimetric determination that

uses permanent color standards fixed into a rotating disk. In field water production this equipment is used primarily for determination of hydrogen ion and chlorine concentrations.

4. Erdlator - Water purification equipment, continuous flow, with flocculation, upflow clarification, filtration, and chlorination combined into a compact unit that may be either truck-mounted, trailer-mounted, or skid-mounted. This is the standard field water treatment equipment in use by the Army.

5. Gph - Gallons per hour

6. Gpm - Gallons per minute

7. Hypochlorinator - Equipment for continuous application of liquid chlorine solution.

8. Millbank Filter - A small fabric stocking-shaped filter used by the British and Australian forces for individual filtration of raw water prior to disinfection.

9. Plastic Vial Comparator - A small plastic tube with a yellow colored band used in visual determination of total chlorine residual at a specific level.

10. Potable Water - Water that is safe for human consumption.

11. Ppm - Parts per million

12. Raw Water - Untreated water.

13. Water Purification Tablets - Used for purification of water in canteens or similar containers. The standard tablet liberates 8.0 mg of iodine (assuming no deterioration).

D. OBJECTIVES

1. Objective 1 - Doctrine and Procedures

Describe and evaluate present doctrine and procedures to determine if they satisfy the requirement for supplying water to tactical units and logistical complexes in RVN, and recommend changes as appropriate.

2. Objective 2 - Water Requirements and Water Sources

Determine water requirements and evaluate the adequacy of water sources to satisfy requirements of selected tactical units and logistical complexes in RVN, and make recommendations as appropriate.

3. <u>Objective 3 - Materiel and Transportation</u>

Evaluate the adequacy of containers, storage facilities, and purification and delivery means for support of tactical units and logistical complexes in RVN, and recommend appropriate changes for improvement.

E. EVALUATION DESIGN

1. <u>Setting of the Project</u>

a. Environment

The study was conducted during the dry season. The Republic of Vietnam lowlands around Saigon encompassing the operational areas of the 1st Infantry Division, 25th Infantry Division, 9th Infantry Division, and 173d Airborne Brigade registered no rainfall for at least 2 months prior to the beginning of the study and remained dry throughout the evaluation. In the central highlands, this same situation was experienced in the Pleiku area (4th Infantry Division) and the Nha Trang-Ban Me Thout area (scattered camps of 5th Special Forces Group). Climatic conditions in the An Khe area (1st Cavalry Division) differed somewhat as the wet season ended in February and the study encompassed the beginning of the dry season in this area. From the standpoint of water supply, the dry season represents the period when both surface and shallow well sources are at their low marks.

The temperatures during the period of the study were normally in the high 90's during the day and rarely fell below 74 degrees fahrenheit during the night. Since the skies were invariably clear, high radiation temperatures were normally encountered by the personnel in open areas. Higher humidity during the latter part of the study increased heat stress, necessitating the intake of larger quantities of water to replenish the moisture lost by perspiration and requiring a higher water consumption rate for hygienic purposes.

b. Military Elements

The data collectors attempted to obtain a representative picture of water supply throughout the operational areas of the US Army tactical units in RVN. The units visited varied in size from division base camps to small Special Forces "A" camps in isolated locations. Operation Junction City, one of the largest tactical operations to date, was conducted during the evaluation period, and water supply conditions were observed under both static and mobile situations.

The major military units visited during evaluation were:

-1st Cavalry Division (AM)

-1st Infantry Division
-4th Infantry Division
-25th Infantry Division
-1st Brigade, 101st Airborne Division
-173rd Airborne Brigade
-196th Light Infantry Brigade
-11th Armored Cavalry Regiment
-5th Special Forces Group
-1st Logistical Command*
-US Army Engineer Command-Vietnam*

The locations visited are shown in figure 1.

2. Methodology

a. Data Collection Methods

The evaluation group consisted of two teams, each composed of one Corps of Engineers officer, one Medical Service Corps officer, one water supply NCO, and one preventive medicine NCO. Upon arrival of the group at a major unit, the teams separated and covered as many subordinate units as time allowed. The ACTIV project officer accompanied one of the two teams.

Standard checklists were prepared and used to insure that both teams obtained comparable data. (See annex A.) The evaluation checklists were designed to collect facts and to solicit opinions from various personnel. The checklists also contained a remarks section which enabled the evaluators to describe in detail the peculiarities of the specific conditions found. Written material in form of unit SOP's, regulations, etc, was collected whenever available. Flight records of two aviation units were examined in detail to determine the amount of water transported by CH-47 helicopters to tactical units during Operation Junction City.

b. Analysis Methods

The collected data were tabulated whenever possible to facilitate interpretation. The variety of conditions encountered and the non-quantitative nature of much of the data precluded a meaningful statistical treatment.

3. Limitations and Variables

The survey was limited to the geographical area in which US Army tactical units were deployed at the time of study. No attempts were made to visit areas which might present special water supply problems in possible future deployment. Large logisistical complexes

* Various subordinate units were surveyed.

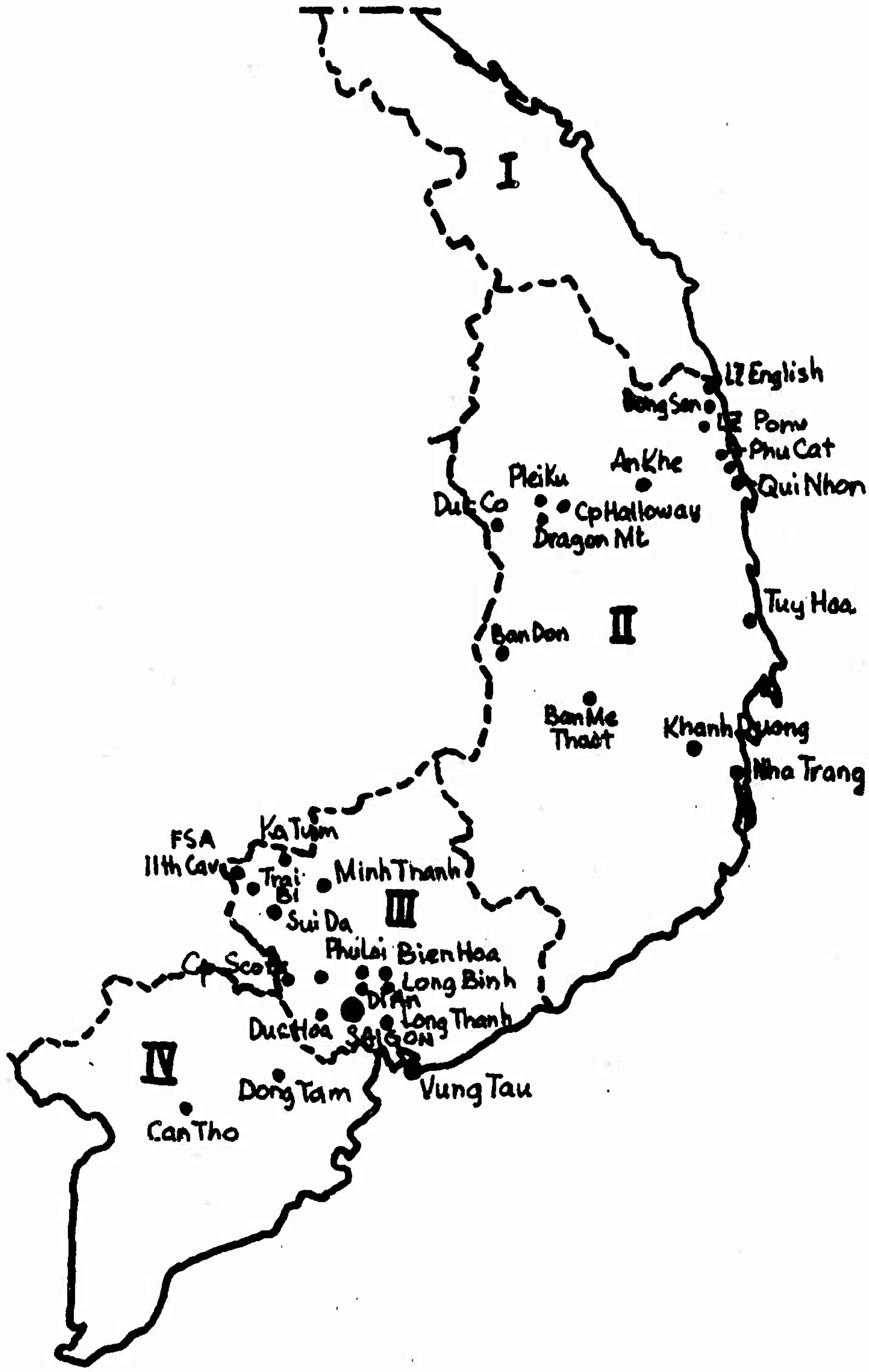

FIGURE 1. Locations of units visited.

such as the Saigon metropolitan district and the Cam Ranh Bay area were omitted from the study because of the peculiarities of their supply systems and associated major problems.

4. Support Requirements

Technically qualified evaluators were placed on TDY to ACTIV for 120 days. The Medical Service personnel were from Brooks Army Medical Center, Fort Sam Houston, Texas; Walter Reed Army Medical Center, Washington, D.C.; and Walson Army Hospital, Fort Dix, New Jersey. The officers were qualified sanitary engineers; one possessed a Phd. The enlisted members were preventive medicine specialists. The engineer officers were from the US Army Engineer Command-Vietnam and the enlisted water supply specialists were from Fort Leonard Wood, Missouri.

5. Time Schedule

a. Temporary duty personnel, two officers and four NCO's, arrived from the CONUS on 31 January 1967. They were joined by two Corps of Engineer officers TDY from the US Engineer Command-Vietnam on 20 February 1967.

b. Data collection was started on 1 March 1967 and was completed on 2 May 1967. The team averaged 4 days with each major unit and made revisits whenever necessary. Supplementary data collection continued during the analysis stage of the evaluation.

II. DISCUSSION

A. WATER SOURCES

1. <u>Types of Water Sources</u>

During World War II and the Korean conflict surface water sources were readily available in mobile tactical situations and US Army water treatment equipment was designed to operate with emphasis on these sources. Surface sources have also been used in the Republic of Vietnam wherever security from insurgent forces could be provided. Generally, military population concentrations were not located in the vicinity of secure surface sources and necessary access road nets were outside of the secure perimeter. The development of ground water sources, therefore, became important in the base camp concept of operation. As a result, an extensive well drilling program was initiated under the overall supervision of the US Army Engineer Command-Vietnam with the actual drilling work being performed by US Army and Navy units and various civilian contractors.

Seven US Army well drilling teams (TOE 5-500C-GE) were assigned to supplement and expedite the above mentioned program. These teams, normally, would have been required to provide only supervisory personnel and necessary equipment for drilling water wells. However, team personnel were found to possess neither the training nor the experience to operate independently and were not trained to supervise others. This problem was temporarily resolved by the inclusion of civilian contractor advisory personnel with each of the US Army well drilling teams. By the time the military operators were capable of working without supervision, they were ready for rotation, and consequently the experience gained in the field was of little value. The problem was further aggravated by the limited number of well drilling personnel needed outside of RVN. These personnel are placed in other career areas and their skills are lost. The doctrine that water well drilling teams be available to supervise a comprehensive well drilling program is sound. However, it appears that a pool of trained personnel has not been maintained to facilitate the implementation of this doctrine under the current operations in RVN.

A summary of the personnel and programs appear in appendixes 1 and 4 to annex A, respectively.

2. Quality of Raw Water

a. Criteria

The criteria for judging the quality of water at its source were established in the Military Assistance Command, Vietnam (MACV) Technical Bulletin 415-2-4 "Standards of Water and Sanitary Systems," dated 29 December 1966. This bulletin requires that the quality of water at the source be such that, upon normal treatment, the finished water meets US Public Health Service recommended drinking water standards. These standards are considerably more restrictive than the minimum potability standards for field water supply accepted by the Armies of the United States, United Kingdom, Canada, and Australia in the SOLOG agreement 125 of September 1966.

b. Salinity

A typical salinity problem reported to the evaluation team was encountered at a military installation located on the lower Saigon River at Nha Be. The problem was being studied in detail by the Officer in Charge of Construction, Naval Facilities Engineering Command, RVN. Extensive sampling of the raw water source was being conducted at the time of this evaluation. Preliminary results indicated that the water salinity was in the neighborhood of 1800 parts per million which is considerably in excess of the SOLOG standards for long term use (600 parts per million).

At Tan An and Nha Trang, when salinity problems were encountered, alternate ground water sources with low salt concentrations were available.

c. Iron Content

The iron standards set forth in the MACV Bulletin could prove to be restrictive in areas near Saigon where ground water supplies exhibit high ferrous iron concentrations. Ferrous iron is difficult to remove by conventional water treatment procedures and additional treatment steps are usually required to oxidize it to ferric form. However, since iron standards are not based on physiological reasons, they have generally not been enforced.

d. Quality Test Kits

In connection with the discussion of the quality of water sources in RVN it is worth mentioning that at the present time there are no simple analysis kits to test for chemical impurities normally encountered in water. A detailed discussion of various attempts to solve this and other problems may be found in paragraph C, WATER QUALITY CONTROL AND TESTING, below.

3. Quantity of Water

a. Criteria

The criteria for water demand were established in the MACV Technical Bulletin 415-2-4 "Standards for Water and Sanitary Systems," dated 29 December 1966. The bulletin states that the average requirements are as follows:

	Water Demand (gal/man/day)
Field	2 to 3
Intermediate (piped water, bathing, mess halls, consolidated sewage treatment)	30 to 60
Temporary (piped water and waterborne sewage)	100
Hospitals (gallons per bed per day)	100

The above local criteria for field water demand are lower than that published in "A Study of Field Water Supply, 1965-1970 (U)" US Army Combat Developments Command (USACDC), April 1965. The USACDC figure for per capita consumption of water considers the use of dehydrated rations and requirements for clean-up water in messing operations.

The local requirement for 100 gallons/bed/day for hospitals is considerably in excess of the figures mentioned in the USACDC study.

b. Base Camp Consumption

At areas with large troop concentrations such as base camps, the personnel charged with base camp development used the MACV figures for planning purposes. The production records at water purification installations were not adequate to allow determination of how close the actual consumption approached the design figures since DA Forms 1713-R (Daily Water Production Log) and DA Forms 1714-R (Daily Water Distribution Log) were not kept properly, if at all. Therefore, no evaluation of the standards could be made, except to state that water restrictions were observed only in three instances, indicating that the desired amount of water was more than the production capacity available in at least these three locations.

c. Field Consumption

To determine drinking water consumption under field conditions, individuals were interviewed in the various major units visited.

Admittedly, such a procedure calls for an estimate by an individual and is very subjective. The sample selection criteria and data obtained from the interviews appear in appendix 2 to annex A.

An overwhelming majority (83 percent) indicated that they consumed 2 to 4 quarts of water a day. In addition to plain water, a rather sizable quantity of other liquids was also consumed. (See figure 2.) The figures obtained from the interviews were compared with estimates from other sources (appendix 5 to annex A), were found to agree rather closely, and amounted to an additional $1\frac{1}{2}$ quarts per man per day.

The consumption rates of potable water for purposes other than drinking were difficult even to estimate. For instance, it is the standard practice in RVN to supply units participating in tactical operations with at least one hot meal per day prepared in forward support areas. Thus, the water usually consumed in preparation of meals was charged against support area consumption rather than field consumption.

One additional use of water under field conditions was generally eliminated: a majority of units used disposable plates, cups, and utensils, during combat operations and, in many cases, in forward support areas. Such practices significantly lowered the water consumption rates.

4. Findings

It was found that:

(a) Army well drilling teams (TOE 5-500C-GE) had little experience in ground water development.

(b) Standards outlined in SOLOG Agreement 125 for long term use were met by the raw water sources in RVN, except for salinity of surface water in delta regions.

(c) Consumption of potable water and other liquids under field conditions was found to be about 5 quarts per man per day. The quantity of treated water available to individuals was generally adequate both under field conditions and in base camp operations.

B. WATER TREATMENT

1. Individual Water Treatment

Generally in the past it was expected that the individual soldier on a patrol, away from an approved water source, would resupply himself with water from any available water source once his initial supply was exhausted. Since surface sources are always presumed to be contaminated, individual water purification tablets were developed so that water of unknown or questionable quality might be disinfected.

FIGURE 2. Supplemental liquid for field consumption.

To determine the status of individual water treatment in RVN, personnel who had participated in patrols were interviewed. A sample was drawn from all major units visited and facts and opinions were solicited from these individuals by one of the members of the evaluation teams. The data obtained have been summarized in appendix 2 to annex A. During the course of these interviews the following was noted:

a) The soldiers preferred to start an operation with as much water as possible. Units participating in certain types of combat operations were issued additional canteens; it was normal for the combat soldier to carry 4 quarts of water and sometimes as many as 6 quarts.

b) If the action lasted for more that 1 day it was the normal procedure to resupply the unit with treated water by helicopter. Rarely did the soldier have to resort to local resupply. In fact, 13 percent of the sample stated that they had never treated water themselves.

c) A surprisingly high percentage of the sample (40 percent) stated that they did not remember receiving any formal instruction in individual water treatment procedures, but 78 percent of them knew the cardinal rules ("drink only approved or treated water, do not contaminate, do not waste treated water"), and the basic reasons for water treatment. Many received instructions from their unit NCO's in RVN. Very few (16 percent) stated that they had read the directions printed on the iodine tablet bottle.

d) Iodine water purification tablets deteriorate when exposed to warm and humid air. One of the readily recognizable signs of deterioration is the change of tablet color from steel gray to white to yellowish brown to deep brown. (See figure 3.) None of the solders interviewed were taught to recognize these deterioration signs. Of the 78 interviewees who knew the color of the tablets they were using, only 40 indicated that they were gray. It is implied that almost half of the users' disinfectant tablets had lost power to some extent.

e) USARV Regulation Number 40-45, "Water Supply," dated 7 January 1967, requires that iodine tablets be used at the rate of one per quart of clear water, two per quart of cloudy water and three per quart of muddy water. The directions printed on the bottle issued to troops state different dosage requirements. The bottle instructions direct the use of one tablet per canteen of clear water and in other cases (as with those manufactured by Wallace and Tiernan, Inc) the directions require the use of one tablet per canteen or other one quart container. Both sets of directions require two tablets for other than clear water. This difference is important because some canteens have a capacity of 2 quarts. The interviews indicated very little adherance to either set of directions. For muddy water the most common

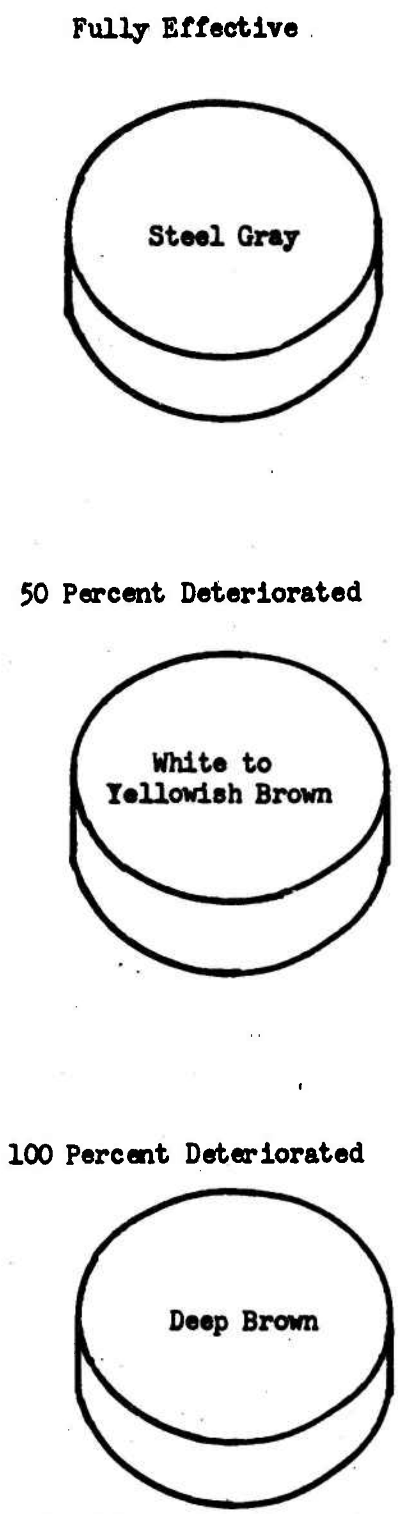

FIGURE 3. Stages of deterioration of iodine water purification tablets.

answer was two tablets per canteen, with the range between one and six. For cloudy water, the most common answer was also two tablets, with the range between one and five. For clear water the most common answer was again two, with the range between zero and four. Only three interviewees stated they used twice as many tablets for two-quart canteens as for one-quart canteens.

f) After adding the tablet to the canteen a certain period of time is required for the tablet to dissolve. Additionally, a further period of time must be allowed for disinfection. The USARV Regulation 40-45 states that the overall waiting period prior to consumption should not be less that 30 minutes. The labels on the water purification tablet bottles indicate that the total waiting period for warm water is only 15 minutes. The interviews indicated that a majority of the users (86 percent) waited more than 15 minutes and only 13 out of 93 indicated they waited 15 minutes or less.

2. Small Unit Treatment

Small unit treatment methods were generally used whenever the number of personnel was too small to warrant the use of standard Corps of Engineers water purification equipment, but when there was a sufficient number of personnel an individual was appointed to treat water for other members of the unit for better quality control.

Evaluators observed that, aside from some Special Forces "A" camps, isolated small units depended on aerial resupply of water which had been treated at engineer water points. A more detailed description of this method appears in pagagraph D, WATER STORAGE AND DISTRIBUTION.

Ideally, purification may be achieved by using a means of filtration such as Filter Unit, Water Purification, Knapsack Type, ($\frac{1}{4}$-gpm capacity FSN 4610-256-4198) or equivalent non-standard equipment. Filtration must be followed by disinfection in order to achieve purification.

Only five Special Forces units observed treated their water at the site. In each case the responsibility was assigned to the team medical specialist who chlorinated the water obtained from local sources in a large container-either a water trailer or 32-gallon galvanized iron (GI) can. Lyster bags were not observed in use. The total chlorine residuals* were found to be, in general, above 5 ppm except in one case where the level was only 2 ppm. Some means for detection of chlorine residual concentration were on hand (disk comparators or plastic vials), except in one case. In this instance, the medical specialist added a fixed dosage that he considered to be

* Chlorine residuals are discussed in detail in paragraph C 1 c.

sufficient for disinfection. The actual residual was found to be in excess of 5 ppm.

No knapsack filters were found in use. Some medical specialists had used them in the past and would prefer to have had them on hand to prepare clear water to wash wounds and minor cuts and abrasions. The existence of the knapsack filter was unknown to the commanders of these small units. When shown a sample, the general consensus was that it was of little use and that the present method of aerial resupply was preferred. Australian Millbank filters were also unknown and personnel expressed no desire to use them.

3. Large Scale Treatment

a. Criteria

Both MACV Directive 40-15, "Sanitary Standards for Water and Ice", dated 29 December 1966 and USARV Regulation 40-45, "Water Supply", dated 7 January 1967 require raw water to be subjected to prescribed treatment before it may be classified as potable. The minimum treatment procedures are:

--coagulation	--filtration
--sedimentation	--disinfection

No exceptions may be made to these minimum requirements without specific approval of the major command surgeon and engineer. The decision to approve a given exception would depend upon the bacteriological and chemical content of the raw water source.

b. Treatment Capabilities

(1) Types of Operations

The organic water treatment capabilities of combat units are austere but sufficient in a mobile tactical situation. When operational units become increasingly fixed and base camps are built, the water demand increases. Initially, such an increase is normally met by supplementary military logistical units or by an increase in manpower and equipment above the normal TOE for the combat support elements. Finally, when base camps grow in complexity, a change is made from field criteria (section II, paragraph A.3) to intermediate demands for consolidated messing and hygienic facilities. During this stage of development, civilian contract operation is usually employed.

From the standpoint of treatment capabilities, water supply in RVN followed the same general pattern.

Organic treatment facilities were initially used to supply water to all of the elements of tactical units. As additional logistical support became available, the organic water supply units were deployed to forward supply areas while responsibilities for base camp support were assumed by Engineer Command and logistical Command facilities. Contracts were later negotiated with Pacific Architects and Engineers, Inc., to provide post engineer-type functions for the larger military population concentrations. These latter operations were carried out under US civilian supervision by third country nationals supported by locally hired personnel.

An inventory of water treatment resources available in RVN has been included in this study. The results appear in appendix 6 to annex A. The sources of the material were TOE's and MTOE's submitted by the various military units to USARV and the monthly Water Supply Status Reports (RCS-AVEN-2) submitted to the USARV Engineer.

(2) Military Operated Facilities

(a) Facilities Organic to Combat Elements

The evaluation teams found that most engineer units were authorized water treatment equipment in excess of their normal TOE. This additional equipment was required because treatment facilities were needed at forward support areas as well as at the main base camp. Surface transportation difficulties encountered in RVN required costly aerial water resupply of company and battalion-sized units operating away from forward support areas. To fill the need for water supply to these smaller tactical units, 600-gph capacity water purification equipment was ordered in January 1967 under the ENSURE program. This equipment is not part of TOE or MTOE of conventional infantry units, but was considered necessary for tactical operations in RVN. At the time data collection was completed this equipment had not been received and water needs were still being served through bulk aerial resupply (section II, paragraph D, WATER STORAGE AND DISTRIBUTION).

(b) Facilities of US Army Engineer Command

The units subordinate to the Engineer Command which support tactical units have limited water treatment facilities at their disposal. This is true whether the facilities are operated by combat engineer battalions or by construction engineer battalions. Available facilities are operated for the benefit of the supported unit and for the engineer personnel. Their total capabilities, as shown in appendix 6 to annex A, slightly exceed the total capabilities of division engineer units.

(c) Facilities of 1st Logistical Command

The cellular water purification teams of the TOE 5-500C series constitute the entire treatment capability of the Logistical Command to support tactical units in base camps. Evaluators found that there are 24 small teams (GF) and 2 larger teams (GG) assigned to post engineer type teams (HD). The total rated water treatment capacity of these units exceeds the rated capacity of both the division engineer units and those of the Engineer Command. Engineer Water Supply Companies (TOE 5-67) are scheduled to arrive in RVN and will be assigned to the 1st Logistical Command, further increasing its treatment capability.

(3) Contractor-Operated Facilities

Pacific Architects and Engineers, Inc., operate water treatment plants in the larger base camps under a repairs and utilities contract with the 1st Logistical Command. The types of units operated by the contractors vary from small 600-gph capacity plants to larger permanent installations. The total rated capacity of the contractor-operated facilities exceeds that of all other sources.

c. Equipment

(1) General

Water treatment equipment organic to brigade and larger units consists of Erdlators of various treatment capacities. These units are capable of giving complete treatment to raw water as outlined in section II, paragraph B.3.a. Some older water treatment equipment (diatomite water purification sets) is still in the system, but has been reclassified as STANDARD-C equipment. Along with these two types of standard equipment, Erdlator-type equipment manufactured in Japan by EBARA-INFILCO was procured for use in larger base camps. A summary of equipment appears in appendix 3 to annex A.

(2) Maintenance of Standard Erdlator Units

Seventy-nine percent of raw water pumps observed in operation were of a standard type. Of these, 58 percent had an average seal life of less than 6 months (based on records examined). A great percentage of repaired units exhibited a very short useful life indicating that new seals were probably installed incorrectly. Evaluators found that water plant operators were inexperienced in Army supply procedures. The supply problems were compounded by the fact that very little direct exchange equipment was available. At the few locations where an NCO (E-6 or E-5) was available to supervise several water points, direct exchange equipment had been procured and was usually available at a rate of one pump in maintenance for every pump in operation.

The life of filter pump seals was in general longer than that for raw water pumps--only 45 percent had a seal life shorter than 6 months. However, in many repaired units, the seals lasted less than 1 month, again indicating poor installation procedure.

Numerous maintenance problems were observed in operation of chemical solution feeders. The most common parts that failed were the diaphragm (36 percent) and the pump body (18 percent). Fuses were, in many cases, difficult to obtain.

Only slightly more than half of the units (56 percent) observed operated on electrical power generators organic to the treatment plant. Of these, 75 percent had a direct exchange policy in force to ensure uninterrupted service. The generator life was, in general, good except for the standard military air-cooled units. These were found to overheat when operated continuously. Another common problem in all generators was clogged carburetors. These could not be removed and cleaned by water point operators, and for that reason required direct support maintenance. The more experienced water point operators preferred the water-cooled generator to the air-cooled models.

Prescribed load lists (PLL) were maintained by only two units. While NCO's in charge of some water teams were aware of their existence, all of the other men denied any knowledge of them. When PLL's were established, no experience factors were considered.

Two other minor maintenance problems observed were:

--manufacturers color code electrical leads differently, reversing the colors of L-3 and L-0 leads (TM 4610-203-12). Some pumps returned from maintenance were thus connected incorrectly and ran backwards.

--air release valves rusted at the spring on the plunger, requiring reorder of the complete valve assembly.

(3) Diatomite Water Purification Sets

Three diatomite water purification sets No. 2 were observed; one in Nha Trang at 5th Special Forces Group Headquarters, one in the MACV compound, and one in Camp Alpha, Tan Son Nhut. Only one maintenance problem was encountered: --locally procured pumps of French manufacture were used in the Headquarters 5th SFC water point and replacement parts had to be locally procured.

(4) Non-standard Erdlator-Type Equipment

Increasing numbers of integral water purification plants manufactured by EBARA-INFILCO in Japan were being procured for use in larger base camps. None of the units were found in operation. Most were still crated in shipping containers. Water treatment personnel of the 65th Engineer Battalion, 25th Infantry Division had attempted to operate two 600-gph capacity units; however, after 4 hours of operation both units broke down and, dueto nonavailability of spare parts, they were unable to repair the equipment. The accompanying manual consisted of a manufacturers component parts catalog which contained no maintenance guides.

(5) Hypochlorinators

The USARV Surgeon and Engineer authorized units that had made proper water analysis tests to treat raw water by chlorination to produce potable water. Under certain conditions, hypochlorinators of the diaphragm type were installed and calcium hypochlorite solution was fed into the discharge side of the raw pump. Maintenance problems associated with such units were minimal, i.e., the check valves had to be kept clean and the solution container kept full of stock hypochlorite solution.

d. Procedures

In accordance with existing criteria (section II, para B 3 a) complete treatment must be given to raw water in the absence of specific permission from major commands to omit the unnecessary steps. Evaluators found that while all units performed the filtration and disinfection steps, only 65 percent (28 of 43) coagulated the water. Further, only 14 units used activated carbon to control odor and taste. A summary of general treatment procedures is in appendix 3 to annex A.

The procedures used in quality control of finished water are discussed in detail in paragraph C, WATER QUALITY CONTROL AND TESTING.

During the evaluation it was found that the necessary water treatment chemicals were made available without delay. Some bulk calcium hypochlorite metal containers had large holes due to corrosion caused by the combination of the chemical with moisture. Plastic package bulk hypochlorite would be preferred under the conditions found in RVN.

e. Personnel

(1) Criteria

Under provisions of TOE 5-155E the engineer battalion of the infantry division is authorized five Erdlator

Units of 1500-gph capacity. Each treatment unit is operated by a team of one specialist (E-4), one private first class (E-3) and one private (E-2). The overall supervision rests with a water supply foreman in the grade of sergeant (E-5). The engineer companies of the separate brigades are authorized fewer Erdlators and correspondingly fewer water supply teams of the same grade structure.

Treatment capabilities are supplemented by water purification teams GC and GD (12 men).* The team chief of the smaller team is a corporal (E-4); he supervises the team consisting of a specialist (E-4), PFC (E-3) and PVT (E-2). The highest enlisted grade authorized for the larger team is a sergeant (E-5). Under his supervision are the team chief corporal (E-4), four specialists (E-4), three privates first class, and four privates.

(2) Types of Personnel

Of the 36 Erdlator units observed in operation, 27 were operated by military personnel. This sample was not representative of the proportion operated by military personnel for the whole of RVN, since large logistical complexes such as Saigon and Cam Ranh were omitted from the survey and civilian-operated units were only surveyed when located in base camps.

Civilian-operated purification units were found to be jointly manned by "third-country" nationals (mostly Korean personnel) and RVN nationals, with the former acting as principal operators and the latter furnishing manual labor. The overall supervision of operations was furnished by Pacific Architects and Engineers, Inc., under contract to the 1st Logistical Command.

Of the 27 military-operated purification units observed during the evaluation, 5 were operated by water supply detachments of the 1st Logistical Command. The remaining 22 were operated by personnel assigned to division engineer units, to separate companies and battalions, or to attached engineer battalions suporting combat units.

(3) Military Grade Structure

The grade structure authorized by TOE was, in general, closely paralleled by actual assignments, but some notable changes were made. In one division, additional treatment units and personnel were authorized under a general order augmenting the capabilities of the organic engineer battalion without changing the grade structure. Three other units had appointed the NCO in charge of water supply an SSG (E-6). Of these only one carried the MOS of the water supply foreman (51N40). The summary of grade structures

* Local TOE's still refer to these units as GF and GG teams.

observed appears in appendix 4 to annex A.

The generally low rank authorized for water treatment specialists caused great job dissatisfaction among operators, with consequent poor motivation and performance. It is of interest that a water treatment team chief in charge of a sophisticated $27,500 unit and whose efforts may affect the health and well-being of several thousand troops is authorized a grade of only specialist E-4, while in the same unit the driver of a 5-ton truck is authorized a grade of E-5. Evaluators noted that it was not uncommon for the treatment unit to be on duty with line troops and beyond the control of the parent battalion. This created a situation in which militarily inexperienced, low ranking men were thrown upon their own devices for maintenance of the equipment and production of the water; the quality of performance in such cases hinged on the morale and motivation of the individuals. Conscientious men performed well, poorly motivated individuals allowed equipment to deteriorate and may have produced water of questionable quality. At least six units were observed under supervision of men completely disinterested in proper water point operation. When the evaluation team NCO's explained various maintenance procedures which needed to be performed these individuals exhibited little interest. During the evaluation, the same water team was observed in two different locations supporting military operations. At both locations the team chief elected not to produce potable water because of the supposedly poor quality of raw water. These actions resulted in undue hardships on the supported units. In both cases, the water treatment unit was distant from the parent battalion. This distance made effective supervision of the water supply NCO extremely difficult and forced costly resupply of line units by helicopters.

Some units recognized the shortcomings of the existing grade structure and appointed full time water supply officers or NCO's from existing resources. Where this occurred, better operation resulted.

f. Training

Water supply specialists are trained to an apprentice level during the 8-week advanced individual training period. They receive training in water testing laboratory procedures and in field operation of the water equipment. Two weeks are devoted to pioneer training, to in-out processing, and to various military and household activities. During this training only 8 days are devoted to actual operation of Erdlator units. Since the program is designed to produce water supply apprentices only, little maintenance and supply procedure training is offered. School-trained apprentices are supposed to function under experienced operators

and to acquire the ability to maintain the equipment by on-the-job training (OJT).

As discussed in paragraph B. 3. c. of this section, most of the equipment failures experienced in RVN were directly traceable to poor operator maintenance. This indicates that the present combination of school and on-the-job training is unsatisfactory, expecially when the importance of maintenance and the uncertainties of OJT are considered. These shortcomings in training are especially significant in RVN since time and experienced personnel are not available to conduct extensive OJT programs.

Existing regulations on chlorine residuals require free available chlorine concentration determination as discussed in section II, paragraph C, WATER QUALITY CONTROL AND TESTING. While the water supply specialists in RVN were capable of running the older, total residual chlorine test, no operators were able to run the required free available chlorine test. This again illustrates the inadequacies of the current water supply specialist training program.

The ROK nationals operating the contractor treatment units were, in general, well-trained in both operation and maintenance. This training took place in Korea, in centers operated by the contractor.

g. Mobility of Equipment

The larger Erdlator unit was designed to be permanently mounted on a standard or special purpose 2½-ton truck chassis, while the smaller unit (600-gph) was designed to be mounted on a special purpose 1½-ton trailer. Both methods afforded good mobility when surface traffic was secure from the enemy.

The evaluators found that in one case a 1500-gph unit was removed from the chassis and transported by a CH-47 helicopter to a location otherwise inaccessible. The unit arrived in good operating order but the 1500-gph capacity was not fully utilized and a 600-gph unit would have been sufficient. This was the only actual instance of airlifting the 1500-gph Erdlator unit in RVN known to the evaluators.

Discussions with engineer personnel connected with production of water disclosed that the smaller 600-gph unit could be used advantageously, especially if mounted on a skid or a base so that it might be transported in a variety of vehicles and aircraft.

Experienced operators who had used both diatomaceous

earth filters and the continuous flow equipment were divided on the desirability of each type. Those who normally operated in forward support areas preferred the older filters, primarily because of simpler maintenance. In one airborne unit that made frequent tactical changes in location, experienced operators preferred the 600-gph Erdlator.

h. Responsibilities for Treatment

(1) Infantry and Airmobile Divisions

Currently the responsibility for water supply to the divisional units is assigned to the supply section of the headquarters company, engineer battalion. The basic mission of the engineer battalion is to furnish engineer combat support and, except for water, is not designed to furnish non-organizational, bulk supply services. The provision of other bulk supply services is normally a mission of the supply battalion in the airmobile division. These supply units have engineer personnel in their headquarters company to supervise the supply efforts of the supply and service (or supply) company. The battalion supports the division and its attached units by providing such bulk commodities as class I, II, III, and IV supplies and also establishes divisional distribution points.

(2) Separate Brigades

The responsibility for water supply in the various separate brigades rests with the engineer companies. Since qualified supervision can be offered only in this organization, no other logical placement can be considered.

(3) Logistical Command

The responsibility for water supply in large base camps and logistical complexes is given to the engineer cellular water purification teams of the TOE 5-500C series. The number and type of these units can be tailored to the amount of support required.

It was found that in RVN a total number of 24 smaller (GF) and two larger (GG) teams were placed under operational control of R&U (HD) teams which provided the overall supervision for the operation. In addition to supervision of the military, the Logistical Command retained supervisory responsibility over contractor operated facilities.

4. <u>Records</u>

a. Plant Operation Records

USARV Regulation 40-45 "Water Supply" dated 7 January 1967, requires the water treatment facility to maintain water supply records in accordance with TM 5-700 "Field Water Supply." The manual requires that three types of records be kept: daily reports, inspection reports, and headquarters summaries.

The Daily Water Production Log (DA Form 1713-R) and the Daily Distribution Log (DA Form 1714-R) form the data base from which other records are maintained. The former shows operating times, chemicals used, and reasons for stoppage. The latter is the record of water distribution to using units and contains the unit designation and the amount of water received. Selected data from these two records provide the basis for the headquarters reports DA Form 1716-R, "Water Point Daily Production Summary" and DA Form 1717-R "Water Point Distribution Summary". These two reports are useful in determining the optimum location of water treatment units, and in assigning supported units to each treatment facility.

Records available indicate that few units made an effort to keep distribution logs. Among those that did, only one required that the unit receiving the water sign for it. Some facilities estimated distribution at infrequent intervals. None of the facilities observed kept production logs as required. Some plants actually estimated their production at figures higher than the rated capacity of the treatment equipment. For example, one base-mounted 3000-gph Erdlator reported daily production of 89,000 gallons during a 16-hour operating day (rated 16-hour capacity = 48,000 gallons).

TM 5-700 also requires that the members of Army medical services inspected each treatment facility at frequent intervals. During each visit an inspection report is prepared on DA Form 1715-R, "Water Point Inspection Report," and a copy is left with the inspected unit. Inspection reports were not seen in any of the facilities visited and neither were daily summary reports prepared by headquarters.

b. Monthly Water Status Report

The USARV Regulation Number 420-2 "Water Supply System - Responsibilities, Procedures and Reports", dated 23 October 1956, requires that major subordinate commanders prepare and submit a monthly water supply status report to the USARV Engineer. This report contains the following information:

--location of facility

--water source

--responsibility for operation and maintenance

--type of purification equipment

--date facility became operational

--hourly production capacity and total quantity produced for period of reports

--storage capacity and quantity of water distributed

--storage facility

--distribution method

--users

--inspections

--projected water requirements

Evaluators found that this report was prepared in some cases and when prepared was a valuable source of information. It must be noted, however, that some of the information appearing in those reports is questionable because it is based on the daily production and distribution logs discussed in the previous paragraph.

5. Potable Ice

a. Criteria

Criteria for the production, handling, storage, and distribution of potable ice are outlined in MACV Dir 40-15, Sanitary Standards For Water and Ice, dated 29 December 1966 and USARV Reg 30-6, Potable Ice, dated 2 February 1966.

The responsibility for assuring potable ice production in accordance with the above criteria lies with the 1st Logistical Command. As in the case of potable water, distribution remains the responsibility of the using units. Production was observed to be efficient, but several distribution problems were observed.

b. Production

The 1st Logistical Command has contracted with Pacific Architects & Engineers, Inc. (PA&E) to operate and maintain ice plants throughout RVN for the production of potable ice. These are two types of standard component plants which may be operated as either single or multiple units. The larger and more common

has a 15-ton per day capacity while the other has a capacity of 3.6 tons per day. Both plants produce a standard 300-pound block of ice. The total capacity of a given plant is related to the number of freezing cells and design of the brine circulating equipment. Pacific Architects and Engineers operates 29 standard 15-ton per day units and 14 3.6-ton per day units. These are in 19 separate locations outside the Saigon area. (See appendix 6 to annex A.)

The ice plants use the circulating brine method to freeze water into a 300-pound block of ice in about 24 hours. No core pumps were observed in use. The liquid in the core was wasted during the process of discharging the block of ice from the freezing container. The overall production, based on operations from 30 March 1967 through 3 May 1967, was relatively stable at approximately 80 percent capacity, or 396 tons per day.

The water used for the production of potable ice received either complete or modified treatment, dependent upon the source of water and subsequent modification approvals from the USARV Surgeon's office. Water treatment equipment operated by PA&E is included in a Summary of Contractor Operated Facilities (paragraph B, appendix 6 to annex A). Tests performed by the evaluators on treated water to be used for the production of ice showed a combined chlorine residual of at least 5 ppm.

c. Distribution

After production, potable ice was subjected to contamination during the handling and shipping processes. (See figures 4, 5, and 6.) The degree of contamination can be related to the distance from the point of production. During normal base camp operations, ice was picked up at the plant loading dock in unit vehicles. The regulations state that a clean, single purpose container must be used for this function. The only single purpose containers observed by the evaluators were used in the 1st Cavalry area for transportation to the forward support areas. A more typical mode of operation was to pick up the ice in the most readily available vehicle or trailor, including those used to haul operational supplies and other base support operations. These vehicles were not conductive to a sanitary operation. This practice was not suprising when the availability of transportation is considered. No special precautions were noted for reducing intransit contamination or melting losses. When the ice arrived at the mess hall it was surface washed with potable water, thus reducing the probabilities of disease transmission. However, when washing was not through and the ice was for direct contact cooling of prepared drinks, an obvious disease transmission potential was present.

When moving ice to the field, the same pickup

FIGURE 4. Potable ice unloaded at helicopter landing site.

FIGURE 5. Same potable ice 1 hour later.

FIGURE 6. Thirty-two gallon GI can, used as ice shipping container.

problems were evident, and were, in fact, multiplied. When moved to a forward support area, the ice was either put into an uncovered container or allowed to wait at a loading zone completely unprotected. In either case, excessive melting was inevitable due to time delays and flight programing. When re-transported to the operational areas, CH-47's and UH-1's were observed with both inside and sling loads. The unprotected ice was thus subjected to continuous surface contamination and melting losses until received by the using unit.

6. <u>Findings</u>

It was found that:

a. The soldiers started an operation with as much water as needed and in most cases had additional canteens in their possession. After the initial supply of water was exhausted, small units were usually resupplied by air with treated water from engineer water points. Individuals were rarely required to treat water themselves. The infrequent use of iodine water purification tablets made the tablet deterioration problem acute.

b. When water purification tablets were used, the proper methods were not followed, indicating inadequate training in individual BCT phase of training.

c. Directions for use of iodine tablets were not uniform in nature, nor were individuals aware of changes in regulations by major headquarters in Vietnam.

d. Knapsack water purification filters were not observed in use in RVN and few small units treated water by chlorination with calcium hypochlorite ampules. Small unit commanders preferred to be dependent on aerial resupply of potable water in lieu of water treatment equipment.

e. Both military and civilian contractor personnel operated Corps of Engineer water purification units in RVN. Erdlators, diatomite water purification sets, and Japanese erdlator-type purifiers were used.

f. Standard electrical raw water and filter pumps operated with Erdlator units exhibited a short seal life. Numerous maintenance problems were observed in the operation of chemical solution feeders and military air-cooled electrical power generators. No realistic prescribed load lists for the Erdlators were observed in RVN.

g. Non-standard, Japanese manufactured erdlator-type

treatment units arrived without spare parts and without adequate maintenance mauuals.

h. All units observed in operation filtered and disinfected the water, but only 65 per cent of the units observed coagulated the water. A large number attempted to control tastes and odors by using activated carbon. The necessary chemicals for water treatment were found to be available.

i. The grade structure of the water supply operators was found to be low, contributing to poor operation and maintenance and job dissatisfaction.

j. Water specialists were only trained to an apprentice level. During this short training period little water equipment maintenance and supply training was given. Reliance on OJT for these two areas was found to be unrealistic in RVN.

k. Six hundred gallon per hour Erdlator units possessed the desirable mobility characteristics necessary for providing treated water to small units under existing conditions in RVN. Additional 600-gph units were requested to supplement the water treatment capabilities at the divisional level. The MTOE submitted by the units did not, however, request the additional personnel for increased operation.

l. The responsibility for water supply to divisional units was assigned to the headquarters company, engineer battalion, whose primary mission was to furnish combat support rather than to supply the division personnel with bulk commodities.

m. The records required by TM-5-700 were seldom kept by units in RVN.

n. The quality of potable ice manufactured in base camps deteriorated rapidly after leaving the ice production facilities. Lack of appropriate storage containers was the main cause for rapid reduction in quality and quantity of ice received by organizations. in remote areas.

C. WATER QUALITY CONTROL AND TESTING

1. <u>Chemical Water Testing</u>

a. Standard Testing Equipment

The Water Quality Control Set (FSN 6630-262-7288) is the only standard analysis kit that can be used for water reconnaissance and routine control. It has been considered to be out-

dated and is retained only as Standard-B. The set provides reagents and equipment necessary to test for CBR agents, coagulation dosages, chlorides, alkalinity, sulfates, and soap hardness. Some of these tests are no longer necessary for the type of water treatment equipment in use. Other tests prescribe out-dated methods. Probably the greatest drawback to the set is poor packaging. This problem could be solved with present state-of-the-art techniques.

Of the 43 operating water treatment units seen during the evaluation, 11 units possessed a complete water quality control set, 5 units had sets with parts missing, and 27 units possessed no water quality control sets. None of the units evaluated had usable reagents. None of the unit operators performed any of the required tests except the residual chlorine determination.

b. Non-Standard Water Analysis Kit

The analysis required to determine if treated water meets SOLOG 125 agreement standards may be sucessfully performed with the standard water quality control set. On the other hand, the number of tests are insufficient if the local standards contained in the MACV TB 415-2-4 are to be enforced, since they require additional tests for nitrates, iron, manganese, and phenolic compounds. To fill this need, at least partially, Direct Reading Engineers's Laboratory kits (Model DR-EL) were procured from Hach Company, Ames, Iowa and five were used by the preventive medicine personnel assigned to USARV. An additional kit was loaned to the evaluation team by US Army Engineer Research and Development Laboratory, Fort Belvoir, Virginia.

The filter photometer which forms the main part of the Hach Company set was not sufficiently rugged to withstand the handling received in shipment from CONUS to RVN, even though it was well-packed. The photometer indicating needle cannot be locked in position for transportation and was damaged in one kit. The needle bearing was extremely rough in all kits, probably due to rust accumulation, and practically any reading could be obtained by tapping the photometer dial.

The test procedures did not fully describe use of all the available chemical reagent blanks nor did they permit a sufficient range of tests for determining drinking water purity.

c. Residual Chlorine Determination

Probably the most important test that was performed routinely on treated water was the determination of residual chlorine concentrations.

The basic doctrine concerning field water supply is stated in FM 21-10 "Military Sanitation" dated May 1957. The portions pertaining

to water supply require that: ". . .In areas where amoebic dysentery, infectious hepatitis, or schistosomiasis are prevalent, the chlorine residual must be increased to 2 ppm or more after 10 minutes of contact time. In any case, the water should not be used until 30 minutes have elapsed after addition of chlorine. . . ."

The basic doctrine has been altered by AR 40-5 "Preventive Medicine" dated 10 April 1964 and TB Med 206 "Viral Hepatitis" dated 13 March 1961. The TB Med 206 requires that in areas where infectious (viral) hepatitis is prevalent, the chlorine dosages should be such that after 30 minutes contact the water should exhibit free available chlorine residual of 5 ppm during the summer season.

Various other authoritative publications touch upon the same area. The FM 5-34, "Engineer Field Data, " dated 30 December 1965 states that water is "safe to drink if it has a (total) residual chlorine content of 1 ppm after a 10-minute contact time." The MACV Technical Bulletin 415-2-4, "Standards of Water Sanitary Systems," dated 29 December 1966 requires that "all drinking water at the point of consumption shall have a free available chlorine residual of 2 ppm after a minimum of 30 minutes contact time." The MACV Directive 40-15, "Sanitary Standards of Water and Ice," dated 29 December 1966, requires that "water will be chlorinated . . to attain a minumum free available chlorine residual of 5 ppm at point of treatment after 30 minutes contact and 2 ppm at point of consumption."

(1) Types of Chlorine Residuals

Chlorine in water may be present in the form of "free available chlorine" (hypochlorous acid or hypochlorite ions) or "combined available chlorine" (chloramine and other chlorinated derivatives). The sum of the free and combined available chlorine concentrations is termed as total residual chlorine. Free available chlorine is a much stronger disinfectant than combined available chlorine and acts to destroy pathogenic organisms more quickly and thoroughly. In neutral acid waters, such as encountered in RVN, free available chlorine may constitute as little as 10 percent of the total residual chlorine (the exact figure depends on concentrations of nitrogenous substances in the water to be treated). Thus, to achieve a free available chlorine residual of 5 ppm, total chlorine residuals considerably in excess of 5 ppm may be needed.

(2) Testing Procedures

The testing procedure used by the water treatment operators in RVN is designed to measure the total residual chlorine concentrations by means of orthotolidine (OT) reagent. This is a very simple test and requires little training. The test to measure free available chlorine residual is more involved and requires additional chemicals and testing procedures.

(3) Equipment for Determination of Chlorine Residuals

(a) Disk Comparator

Both the water supply operators and the preventive medicine personnel are equipped to determine the total residual chlorine concentrations in treated water. The basic test item is the Comparator, Color, Hydrogen Ion and Residual Chlorine (FSN 6630-542-1564). The glass cells and the easily damaged color disks were in short supply, and substitute glassware such as a water tumbler was used or the color was estimated by the operator against a damaged disk. (See figures 7 and 8.) This was observed in 8 of the 43 water treatment units visited. Two additional units had no provision to make chlorine residual determinations and two other units used comparator vials discussed in the next paragraph.

(b) Comparator Vials

Chlorination Kit, Water Purification, Type I (FSN 6850-270-6225), designed to be used for small unit water treatment, contains three plastic vials with calibrated color bands for testing the total residual chlorine concentration in the treated water. As the usual concentrations of concern to the US Army are 1, 5, and 10 parts per million chlorine residual, these three types of vials are included in the standard kit.

Since the local regulations and directives (US Army Pacific, Military Assistance Command Vietnam, and US Army Vietnam) allow the residual chlorine concentration to be as low as 2 ppm after the treated water has been delivered to the unit, it was decided that an additional vial should be developed so that the presence of this intermediate concentration could be determined. Since small unit treatment methods for water disinfection are rarely used in RVN, the remainder of the chlorination kit was no longer necessary and the calcium hypochlorite ampules were discarded.

A request for procurement under the ENSURE system was submitted and the items classified as Orthotolidine Testing Kits with 50 tablets of 2ppm residual chlorine in water (FSN 6850-979-9489) were received in RVN in October 1966. The initial procurement was of 15,000 kits and the contemplated basis of issue was 3 kits per month for every 100 men. The availability of such a kit would enable a unit to make periodic residual determinations in water from trailers, coolers, and similar containers.

The requested comparator vials have been received and the initial issue was stocked by the 32nd Medical Depot. Upon receipt, the 1st Logistical command was to advise the units of availability and the basis of issue. The advance platoon of the depot,

FIGURE 7. Disk comparator showing typical condition.

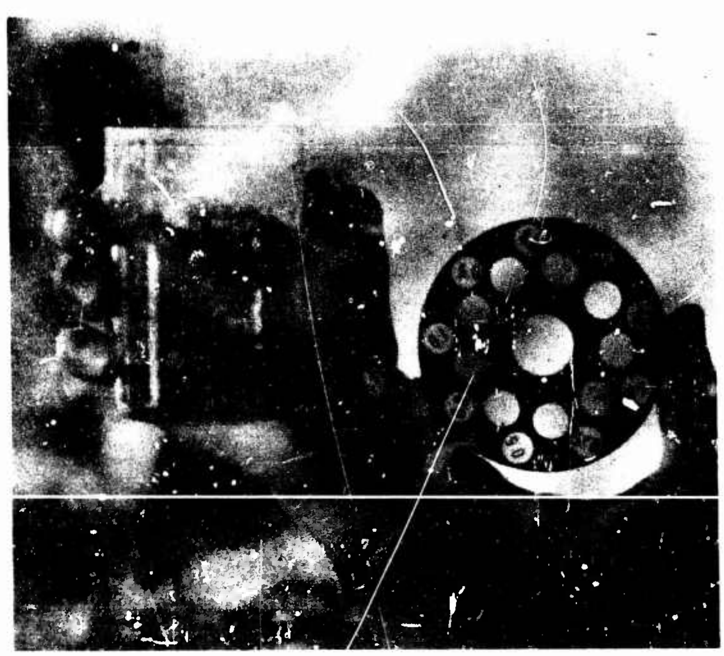

FIGURE 8. Makeshift comparator using water tumbler and disk from disk comparator.

located in the Saigon area, received 6902 kits. Of these, 65 kits were issued as of 18 May 1967. These figures were supported by the fact that the evaluators failed to find any 2 ppm vials in the units visited.

Some water supply personnel did have the vial comparators (1, 5, or 10 ppm) on hand and were using them instead of the disk comparators they are authorized. The source of these vials was found to be the water purification chlorine kits. The color bands indicating the chlorine concentration were found to be seriously discolored from use and hence no reliance could be placed on determinations made with them.

2. Bacteriological Testing

a. Criteria

The USARV Regulation 40-45, "Water Supply," dated 7 January 1967, requires that potable water be subjected to bacteriological examination. As a minimum, weekly samples have to be withdrawn from all water supply points (plants), representative points in distribution systems, and a representative number of the water trailers or trucks used to haul potable water.

b. Equipment Procedures

Water Testing Kit, Bacteriological (FSN 6665-682-4765) is the primary tool for bacteriological analysis of potable water. One such kit is available to each division preventive medicine officer and numerous kits are found at higher echelons. The ampuled bacterial culture media (MF-Endo Broth) was in very short supply in RVN, and what was available showed storage deterioration. This deterioration was indicated by extensive precipitation of the inhibitory dye. Additional difficulty was encountered with the supply of the bacterial microporous (membrane) filters which are required for the test. The supply system substituted oil testing filters which were completely unsuitable.

3. Responsibilities for Control

a. Criteria

The responsibility for control of water quality rests both with Corps of Engineer and with Army Medical Service personnel.

The USARV Regulation 40-45 requires that the water supply operators perform free available chlorine residual determinations at least once every hour during periods of water production.

Organic medical personnel at unit level are required to

make periodic chlorine residual determinations at different locations such as water trailers, trucks, water faucets, coolers, etc, and to report unsatisfactory results, if any, to the water point operator and the unit or area surgeon..

Unit and area surgeons are required, in addition to chlorine residual surveillance, to institute a bacteriological sampling program. They may be assisted by the preventive medicine personnel of the Logistical Command.

b. Personnel and Training

Corps of Engineer water point operators were neither trained nor equipped to perform the free available chlorine determination. The poor condition of their residual chlorine comparators in some cases precluded meaningful total residual chlorine readings.

At the division level, the preventive medicine officer is available to furnish guidance to water supply personnel. However, no enlisted preventive medicine personnel are assigned at that level. Therefore, the amount of time and effort that can be devoted to detailed control of potable water quality is limited. The necessary equipment and skill are not available to make the free available Chlorine residual determinations and bacteriological analyses of potable water.

The majority of preventive medicine personnel are assigned to the preventive medicine service unit augmented by TOE 8-500 teams. This unit provides general preventive medicine support to all USARV units. The unit has sufficient personnel to conduct special studies and a limited amount of routine surveillance of the water quality (both chemical and bacteriological).

The intensity of medical surveillance of the water supply points was found to vary from unit to unit. Some treatment units were visited by the Army Medical Service personnel daily, others at very infrequent intervals, if at all. There were few cases where samples were collected for bacteriological analysis.

4. <u>Findings</u>

It was found that:

a. Standard water quality control sets were available in RVN, but were not used by all personnel. These sets were adequate to perform the chemical tests to determine conformance with SOLOG 125 standards, but not for the additional tests that were required by local MACV TB 415-2-4. Non-standard Direct Reading Engineer Laboratory kits manufactured by Hach Company were used for this purpose, but were found to be unreliable under the conditions found in RVN.

b. Current US Army regulations on water disinfection are written in terms of free available chlorine (FAC) residuals. The local regulations require a FAC residual of 5ppm at the production site and no lower than 2ppm at the point of consumption.

c. A significant number of water treatment facilities are without adequate means to determine chlorine residual dosages. The comparator vials designed for use by unit medical personnel were received in RVN under ENSURE program in October 1966 but were not distributed to the units by the time of evaluation.

d. Ampuled bacteriological media and microporous filters were in short supply in RVN, necessitating a reduction in bacteriological testing program. The small amount of ampuled media on hand showed storage deterioration.

e. Water treatment operators were not trained to perform FAC residual determinations, nor did they have the necessary solution on hand.

f. The lack of enlisted preventive medicine personnel at division level make detailed surveillance of water quality very difficult, since the division preventive medicine officer had little time to devote to routine control of water.

D. WATER STORAGE AND DISTRIBUTION

1. Canteens

a. General

Much effort has been expended in developing individual canteens for various special purposes and in testing foreign-made containers. The foreign types evaluated varied to a small degree in diameter of the neck opening and in volume but essentially were similar to the standard US canteen.

Three types of canteens were encountered by the evaluation team in RVN. The two standard metal and plastic 1-quart canteens and the recently developed collapsible 2-quart canteen. To elicit the information with regard to use, problems encountered, and individual preferences, the evaluation teams conducted structured interviews of individuals in all units visited. The individuals selected were those who participated regularly in field operations. A summary of data collected is shown in appendix 2 to annex A.

b. Canteens on hand

Only 10 percent of the men interviewed had the standard metal canteen. The most common type encountered was the standard one-quart plastic canteen. The infantry and airmobile divisions were equipped with this type almost exclusively. The airborne units were equipped with both the plastic 1-quart and the collapsible 2-quart canteens developed in response to SDR 139 (C) a (8), but without the semirigid canteen cup.

c. Preferences

The men who mentioned that they had an occasion to use more than one type of canteen were asked to state their preferences. Of those personnel not equipped with the collapsible 2-quart canteens the overwhelming majority preferred standard plastic canteen. The reasons for this preference did not appear to be based on fact. Examples of such reasoning were the water in plastic canteens keeps cooler and the water is easier to treat.

In the airborne units which were supplied with both the plastic 1-quart and the collapsible 2-quart canteens, the collapsible type was highly preferred. Further interviewing showed that the individual really preferred to have both the plastic and the collapsible canteens. The reasons for wanting to have both on hand were that the collapsible canteen was hard to drink from and fill from surface sources. During field operations men would transfer water from the collapsible to the standard canteen for consumption and fill the collapsible

canteen with the standard one when both were empty. The men also used the collapsible canteen for other than its intended use (pillows to sleep on and to sit on).

d. Problems Encountered

The threading of the neck on the 1-quart plastic canteen was rather weak and many of the users (almost 50 percent) complained about cross-threading and thread stripping. Another problem was the breaking of the loop fastening the cap to the canteen body.

The standard metal canteen showed considerably fewer problems: only corrosion was mentioned.

While complaints about the collapsible 2-quart canteen were few, most indicated that it could be punctured very easily under field conditions, especially when carried without the outer nylon cover, which was common in one unit since not enough covers were available. The opinions on the shoulder strap were evenly divided: some men preferred the neck strap since it lightened the load on the belt, others preferred the belt clips. The stainless steel strainer was normaly removed and discarded as soon as the new canteen was received.

2. Intermediate Size Containers

a. Free-Drop 3-Gallon Container

Free-drop 3-gallon water containers were received in RVN for testing purposes. The units which received these containers submitted test results directly to CONUS agencies. When all major units were queried, an answer was received only from the Headquarters of 5th Special Forces Group. The results indicated that no failures were observed when the containers were dropped from a variety of altitudes and at a variety of air speeds. No data were obtained on reuse of containers.

b. Five-Gallon Water Container

(1) Rigid Containers

Several types of rigid water containers were comparison-tested by troop units in RVN. The evaluation was conducted by ACTIV and the results appear in letter report of evaluation entitled "Can, Plastic, 5-gallon Water" (ACL-91/67) dated 26 April 1967. The items compared were:

—standard metal 5-gallon can

—locally procured plastic 5-gallon can with narrow neck opening

--Canadian plastic 5-gallon can with wide neck opening

Units were asked to comment on their preference and also to state other desirable features not incorporated in any of the above.

The Canadian 5-gallon plastic water can was preferred to other types and was sufficiently durable with the exception of the cap fastening collar.

While the large opening was preferred in filling and cleaning, the test units suggested that a second smaller opening was needed so that canteens could be filled easily without waste.

Since the 5-gallon can is the most readily available container at the unit level, it is widely used for both storage and distribution of water. (See figures 9 and 10.) Units with heavy equipment, such as artillery batteries, use them during movement to supplement the storage afforded by the individual canteens. Filled cans were distributed widely among the living quarters in base camp areas. When aerial resupply of water was undertaken by helicopters, 5-gallon cans were the containers most often used.

(2) Collapsible Container (Lug-a-Jug)

The collapsible containers have two advantages over the rigid ones. They are normally made of thin gage lightweight material and, when empty, may be collapsed to reduce bulk. However, absence of rigidity when full makes them difficult to stack and unstable when stacked. This feature also makes them difficult to employ in filling other containers, such as canteens.

These findings were brought out in interviews with personnel of the 1st Cavalry Division. Opinions were mixed as to the acceptability of the collapsible item, but the predominant feeling was that rigid containers were preferable.

(3) Rigid Container with Spout

During the course of evaluation non-standard round, wide mouth 5-gallon containers with a spout were observed in general use in the 1st Infantry Division. (See figure 11.)

The users indicated general satisfaction with the item. The wide mouth enabled easy filling and cleaning and the spout on the bottom facilitated dispensing the contents. The spout, however, was found to be sensitive to rough handling and the round shape took up additional space in stacking. Some units fastened the container to the ¼-ton truck for use in field operation and at construction sites.

FIGURE 9. Filling 5-gallon water cans at water point.

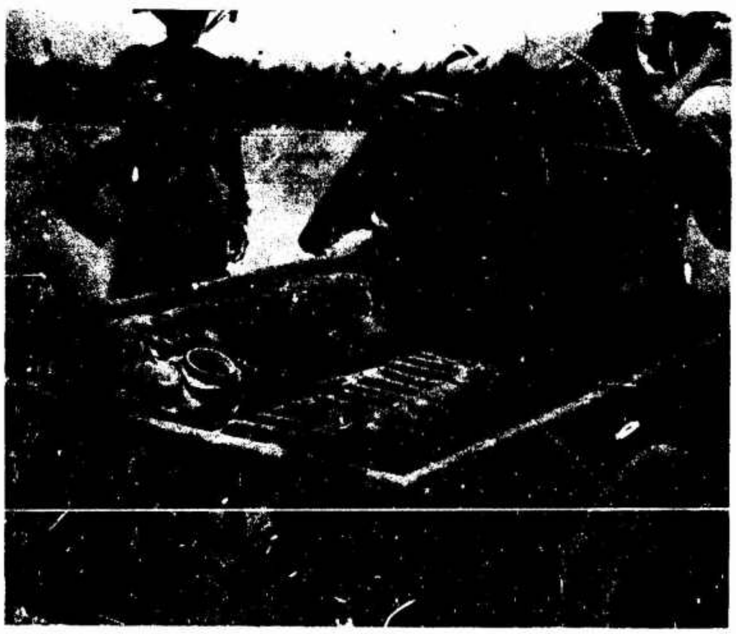

FIGURE 10. Five-gallon water cans for potable water and 55-gallon drum for non-potable water transported together.

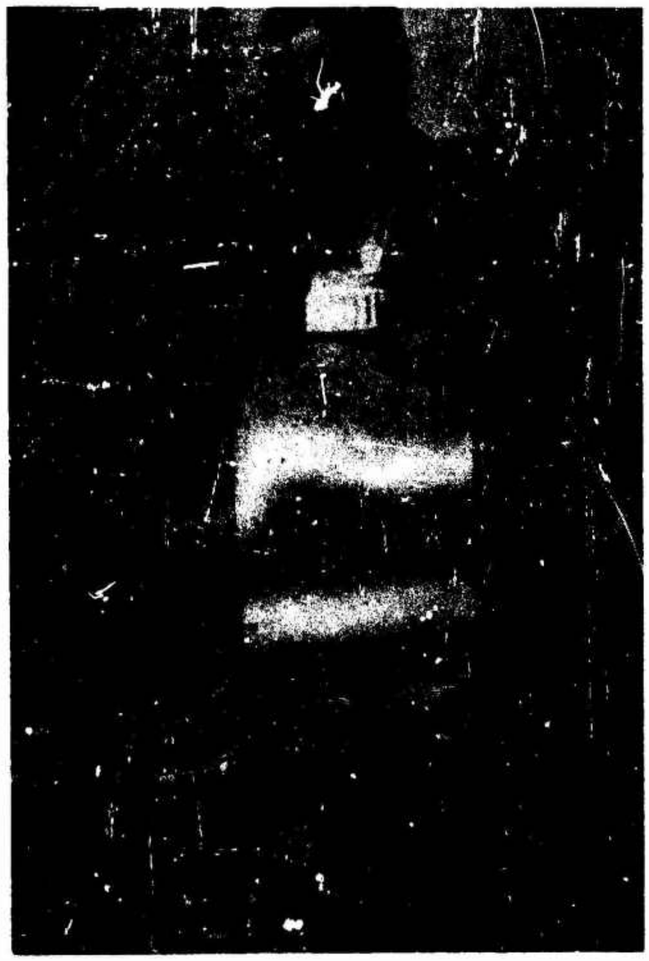

FIGURE 11. Five-gallon wide-mouth container showing position of spout.

Sometimes the containers were used at forward support areas for drinking water and also as shower units.

c. Lyster Bag

The only lyster bags found in use were located in USARV Headquarters Compound at Tan Son Nhut. This in itself is a rather startling finding since water kept in shaded lyster bags is usually cooler than that kept in 5-gallon metal or plastic cans and 400-gallon water trailers. The evaluators could not elicit any reasons for this lack of use from the unit commanders interviewed, except that iced drinks were usually available at the mess halls and that 5-gallon cans were used in billets and tents because these were easier to handle.

d. 55-Gallon Drums

(1) Conventional Drums

Conventional 55-gallon metal drums were observed in use extensively for storage and distribution of water. Since the containers arrived in country normally filled with POL items, they were rarely used for potable water, but served mostly as storage reservoirs for small showers and washing facilities, especially in those cases where shower water was heated in the storage container with immersion heaters.

(2) Collapsible 55-Gallon Containers

The collapsible 55-gallon bladder had just arrived in-country and was being user-tested at the 1st Infantry Division. No test results were available at the time this evaluation was completed.

3. Standard Large Mobile Containers

a. Containers on $1\frac{1}{2}$-Ton Trailers

The more recent 400-gallon fiberglass and older 250-gallon metal water trailers are authorized for a variety of units. The inventory of these containers is shown in appendix 7 to annex B.

While the total figure of trailers on hand may appear high (1187), the authorized number of trailers are inadequate for some units due to peculiarities of tactical conditions in RVN. For example, when an infantry unit begins an operation it usually leaves its support elements at the base camp. The commander has two alternatives: leave his water trailer behind with the mess section or take it with him with the maneuver elements. Neither solution is considered satisfactory. Therefore, additional trailers were requested in the MTOE because unit level permanent potable water storage facilities were rarely available in base camp. This situation is aggravated by the fact that

both potable and non-potable water must be hauled to the unit area and containers cannot be used interchangeably.

The 400-gallon water trailer is the most common at the potable water points in the base camps and forward support areas of the infantry units. The trailer is used extensively for resupply when unit locations are accessible by ground transportation.

The infantry divisions' 1½-ton trailers were also used for aerial resupply of forward units of company size and larger. (See figure 12.) During Operation Junction City, units of the 1st and 25th Infantry Divisions were supported by two assault support helicopter companies (CH-47). The data shown in appendix 8 to annex A indicate the scope of operation. Units of the two divisions were resupplied at the rate of 14,400 gallons of water per day by this method alone.

Helicopter transport is far from ideal, however, because the 1½-ton water trailer is a very awkward sling load. Further, the low payload-to-gross-weight ratio does not result in good aircraft utilization.

b. Tank Trucks

Water tank trucks, 2½-ton and 5-ton, are not authorized in division TOE's. Airborne and airmobile units have an insufficient authorization of 1½-ton water trailers, and have been authorized 900-gallon or 1000-gallon water tank trucks by MTOE (appendix 7 to annex A).

The logistical complexes at Qui Nhon and Cam Ranh were each authorized one TOE 5-500C water transport team (GH) assigned to the 1st Logistical Command.

Water tank trucks were not observed in the infantry units. However, a number of POL tank trucks and semitrailers assigned to the Division Support Command were observed hauling non-potable water.

To obtain information on various containers used to transport water, a 9-day survey was performed at one of the large base camps. These data appear in appendix 8 to annex A. A large proportion of the total amount of non-potable water was hauled in POL tank trucks.

4. Large Collapsible Containers

Two hundred fifty and five hundred-gallon collapsible water containers have been used extensively in airmobile and airborne units for storage and distribution of potable water. (See figure 13.) Their use for storage is dictated mainly by low availability of rigid containers. At fixed installations, the absence of rigidity is a drawback, especially during filling and emptying operations.

FIGURE 12. CH-47 helicopter with 400-gallon water trailer sling loaded.

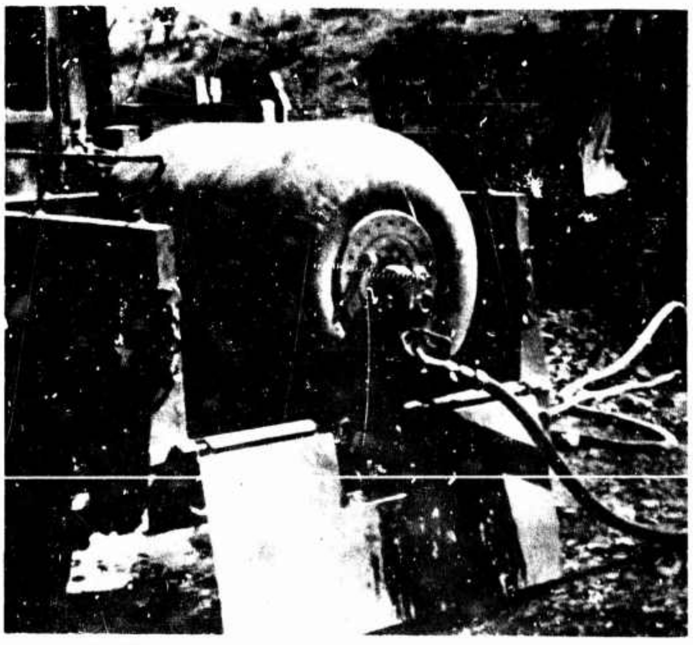

FIGURE 13. Two hundred fifty gallon collapsible tank used for distribution of water.

The main storage facility for the potable water point at one base camp was a 21,000-gallon petroleum bladder, which had not been used for POL storage. The bladder had been elevated and was used for dispensing water into vehicles.

When used for aerial resupply for company-sized and larger airmobile or airborne units, the large collapsible containers are in great demand and are preferred by aviation personnel. Water in these containers presents a less awkward sling load configuration in comparison to 1½-ton water trailers and affords a higher payload production.

5. Improvised Large Storage Containers

Since basic TOE's do not provide equipment for storage of water at the user's end, the majority of large storage facilities have been improvised from a variety of containers. (See figure 14.) one of the most common types encountered was a small elevated structure with one or more aircraft wing tanks. This storage configuration was primarily used for storage of water at shower and messing facilities. Just as common were napalm containers and large reusable engine containers. These latter two types are often found permanently mounted on tactical vehicles to serve both storage and distribution functions. (See figure 15.) Somewhat less frequently observed were 250-gallon rigid fiberglass fuel cells, sometimes with FLAMMABLE markings still visible. (See figure 16.)

While the larger Navy cubes were seen, their number was less than anticipated, apparently caused by their poor availability to tactical units. When observed, they were usually employed as part of fixed water storage facilities. (See figure 17.)

6. Large Fixed Storage Facilities

Large fixed water storage facilities were normally associated with base camp water treatment units and non-potable water pumping stations. When storage facilities were not sufficient, long waiting lines of tank trucks and water trailers were observed. Interviews with the drivers revealed that waiting periods were as long as 5 hours, with an average waiting period of about 2 hours. The longer waiting times occurred when a large tank truck was being filled. The insufficient storage capacity problem was sometimes further aggravated by inadequate elevation of tanks or low discharge rates of the distribution pumps.

Small storage capacities were frequently encountered at most military operated water supply points because they were restricted to TOE limits, unless additional storage facilities had been authorized or improvised.

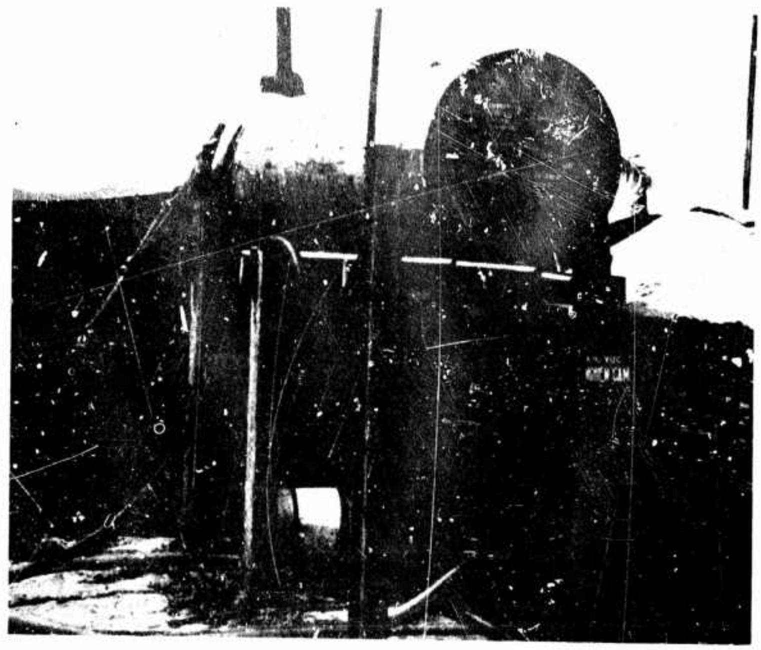

FIGURE 14. Typical unit water storage facility.

FIGURE 15. Improvised water trailers.

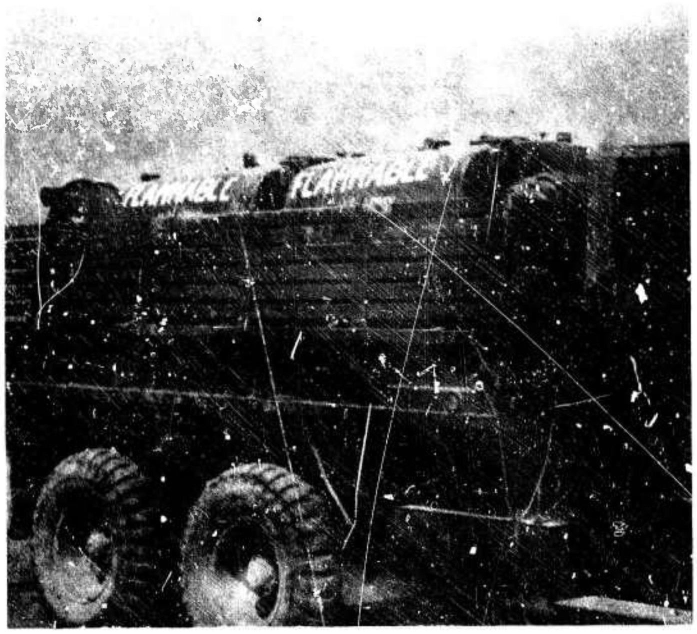

FIGURE 16. Fuel cell used for potable water.

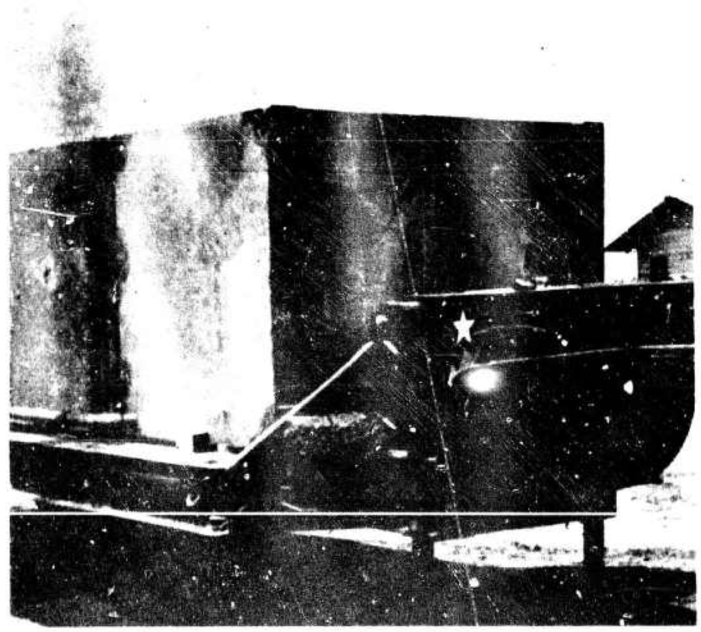

FIGURE 17. Improvised water tanker using Navy cubes.

The contractor-operated facilities observed were normally found to be well-provided with storage facilities. An inventory of these storage facilities appears in appendix 7 to annex A.

7. Findings

It was found that:

a. The standard plastic 1-quart canteen was in universal use in RVN. Airborne units were also equipped with collapsible 2-quart canteens which served to supplement the amount of water carried by soldiers on combat operations.

b. The collapsible 2-quart canteen was well-liked as a supplementary container. Most users who had occasion to compare the two plastic canteens preferred to have both on hand, but if limited to one kind, the collapsible 2-quart canteen was chosen.

c. The threads of the neck on the 1-quart plastic canteen were weak and this resulted in frequent cross-threading.

d. Collapsible 2-quart canteens were punctured easily, especially when carried without the outer nylon cover. The stainless steel strainer was normally removed and discarded as soon as the new canteen was received.

e. Various rigid 5-gallon water containers were tested and the results were published by ACTIV in letter report of evaluation "Can, Plastic, 5-gallon Water" (ACL-91/67), dated 26 April 1967.

f. Lyster bags were rarely used in RVN.

g. The number of water trailers authorized in divisional units was, in general, inadequate. To supplement organic water hauling capabilities, additional water trailers and tank trucks were authorized, in some cases under MTOE. Improvised containers were widely used, testifing to the need for additional water distribution equipment.

h. During an operation smaller units were often resupplied with water by air. Since infantry divisions did not have collapsible 250-gallon or 500-gallon water bladders, the helicopters sling-loaded the standard water trailers, which resulted in poor utilization of aircraft pay load capabilities.

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III CONCLUSIONS AND RECOMMENDATIONS

A. WATER SOURCES

1. It is concluded that:

a. To assure continuous supply of potable water in the operational environment in RVN it is necessary to consider ground water as a primary source for base camp operations.

b. Members of US Army well drilling teams lack the necessary experience properly to supervise drilling operations in the development of ground water resources.

c. Raw water sources in RVN satisify the quality standards set forth in SOLOG Agreement 125 except for salinity of surface waters in the delta regions.

d. The quantity of potable water available to individuals is adequate.

2. It is recommended that:

a. The Corps of Engineers institute a comprehensive and continuing training program for the development of water well drillers. Such personnel should be afforded continuing experience in CONUS to maintain their proficiency.

b. Local directives be modified to allow for greater flexibility in chemical standards not affecting the health of personnel, provided that the minimum quality standards of the SOLOG Agreement 125 are observed.

B. WATER TREATMENT

1. It is concluded that:

a. Units on operations rely to a great extent on aerial resupply for water. Along with ammunition, rations, and other necessities, aircraft are made available to transport potable water to troops in the field. Individuals rarely need to treat water themselves.

b. The infrequent use of iodine water purification tablets makes the tablet deterioration problem acute.

c. Insufficient emphasis is placed on training in field methods of water treatment.

d. The instructions appearing in various official publications and on the tablet container labels are inconsistent.

e. Small unit commanders preferred to depend on aerial resupply of potable water rather than use water treatment equipment themselves.

f. The 600-gph capacity water purification equipment was ordered in January 1967 to supplement divisional TOE authorizations. The submitted MTOE did not reflect additional personnel requirements.

g. The generally low rank authorized for water treatment specialists caused job dissatisfaction among operators, with consequent poor motivation and performance.

h. Erdlator failures were directly related to inadequate training and experience in maintenance of the equipment.

i. Japanese manufactured integral water purification plants of various capacities have been received in RVN without adequate spare parts or maintenance instructions.

j. The versatility of the 600-gph Erdlator makes it preferable to larger water purification equipment under the highly mobile operating conditions found in RVN.

k. The basic mission of the combat engineer battalion is to furnish engineer combat support and, except for water, it is not designed to furnish non-organizational bulk supply services. These services, on the other hand, are within the scope of normal responsibility of the support command.

l. Daily operational reports and periodic medical inspection reports were not being properly prepared.

m. The amount and quality of potable ice received in the field is significantly reduced as a result of inadequate handling and shipping procedures.

2. It is recommended that:

a. A new packaging process be designed to improve the useful life of the water purification tablet.

b. More emphasis be placed on methods of field water treatment during the BCT. In addition to material contained in I 21-10,

the personnel be taught to recognize signs of deterioration of water purification tablets.

c. The local instructions regarding the number of tablets and the waiting period after use be made consistent. If the appropriate local regulations are made more stringent than those contained in CONUS training doctrine, that steps be taken to acquaint the personnel arriving in RVN with these changes.

d. Additional water supply personnel be requested to operate and maintain 600-gph Erdlators.

e. An advanced water supply operation course be established within the CONARC school system. Qualifications for the course should include prior field experience as a member of a water supply team. The subject matter should emphasize water point supervision, supply, maintenance and quality control procedures.

f. The grade structure of the water point supervisory and operating personnel be elevated in consonance with the responsibilities of this important operation. The proposed changes appear in annex B.

g. All non-standard equipment procured for use in RVN include a realistic basic load of spare parts and maintenance and supply manuals commensurate with other standard equipment publications. Procurement contracts should include follow-on spares when equipment is non-standard and non-interchangeable with that in the existing supply system.

h. The responsibility for water supply be critically reviewed with the possibility of relocating personnel and equipment to the supply and transportation battalion of the division support command. The proposed changes appear in annex B.

i. Special purpose containers for handling and storage of potable ice under field operating conditions be designed and furnished troop units in RVN.

C. WATER QUALITY CONTROL AND TESTING

1. It is concluded that:

a. Results of chemical analyses performed in the theater at the time of evaluation were not always valid due to the shortcomings in the existing chemical analysis equipment.

b. The chlorine residual comparators in most cases were in poor condition and total chlorine residual and free chlorine determinations could not be effectively performed by the water supply personnel.

c. The divisional (separate brigade) units have insufficient preventive medicine personnel to assure the maintenance of quality standards in accordance with existing regulations.

2. It is recommended that:

a. A standard means for performing necessary chemical analyses be made available to both engineer and Army medical service units.

b. If the standards are written in terms of free available chlorine residuals, both the engineer water supply and the preventive medicine personnel be trained and equipped to perform the necessary tests.

c. Additional preventive medicine personnel be authorized to assist the division preventive medicine officer in surveillance of water quality.

D. WATER STORAGE AND DISTRIBUTION

1. It is concluded that:

a. The threads of the standard plastic canteen are weak, which result in frequent cross-threading.

b. The plastic collapsible 2-quart canteen is susceptible to puncture in field operations. The stainless steel strainer is considered an unnecessary hindrance by the majority of the users.

c. The present authorizations of the 1½-ton water trailers are inadequate throughout troop units in Vietnam.

d. Tactical vehicles have been converted to improvised water hauling equipment.

e. Insufficient numbers of TOE 5-500C water hauling teams (GH) are assigned to base camp operations.

f. Since infantry divisions are not authorized large collapsible water containers, 1½-ton trailers are airlifted to units engaged in tactical operations.

2. It is recommended that:

a. The threading on the standard plastic canteen be redesigned.

b. The 2-quart collapsible canteen be made more durable and puncture resistant.

c. The stainless steel strainer in the 2-quart collapsible canteen be eliminated.

d. The authorizations of 400-gallon $1\frac{1}{2}$-ton water trailers be liberalized to meet tactical requirements.

e. Additional TOE 5-500C water hauling teams (GH) be assigned for operation at base camps and readily accessible forward support areas.

f. Large collapsible water containers be authorized for infantry divisions for aerial water resupply to tactical units that do not have the capability of producing potable water at forward locations.

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ANNEX A

DATA SUMMARIES

This annex provides statistical and related data to support the report. Raw statistical data have been reduced, equipment and operational problems have been noted, and specific programs have been outlined. Information received from structured interviews, as well as analysis of reports and records, has been included.

Each subject area has been organized into an appropriate appendix, as follows:

APPENDIX 1. Well Drilling Program

APPENDIX 2. Summary of Answers to Interviews on Individual Treatment

APPENDIX 3. Observed Large Scale Treatment Equipment and Procedures

APPENDIX 4. Personnel and Training

APPENDIX 5. Soft Drink Importation

APPENDIX 6. Inventory of Water Treatment Facilities

APPENDIX 7. Water Containers and Storage

APPENDIX 8. Distribution of Water

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APPENDIX 1 TO ANNEX A

WELL DRILLING PROGRAM

a. INVENTORY OF EXISTING AND PROPOSED SITES

(1) Sources of Data

Two sources of site data were made available to the evaluation team: US Army Engineer Command Vietnam, and 1st Logistical Command. Both sources agreed except for minor conflicts. These conflicts are noted in the following summary.

(2) **Summary of Data**

Location		Number of Wells Drilled: Total	Dry	Test	Salt	Average Depth (ft)	Total Yield (GPM)	Wells Proposed
I Corps Area								
Quang Tri	(YD35)	-	-	-	-	-	-	1
Phu Bai	(YD91)	-	-	-	-	-	-	1
Da Nang	(BT08)	4	-	-	-	115	198	0
Chu Lai	(BT50)	-	-	-	-	-	-	4
II Corps Area								
Pleiku	(AR85)	11	-	-	-	317	594	7
An Khe	(BR55)	3	-	-	-	43	136	7
RTE 19	(BR93)	4	4	-	-	unk	0	4
ROK Valley	(BR92)	6	-	-	-	101	518	1
Phu Tai	(CR02)	7	3	1	-	96	435	3
Qui Nhon	(CR12)	9	-	-	-	139	913	0
Cheo Reo	(BQ28)	-	-	-	-	-	-	1*
Tuy Hoa	(CQ23)	10	-	-	-	133	924	0
Ban Me Thout	(AQ84)	-	-	-	-	-	-	2*
Duc My	(BP89)	-	-	-	-	-	-	2
Ninh Hoa	(CP08)	2	-	-	-	57	unk	1
Nha Trang	(CP05)							
MACV		2*	-	-	2*	110	113	1

Location		Number of Wells Drilled: Total	Dry	Test	Salt	Average Depth (ft)	Total Yield (GPM)	Wells Proposed
Camp McDermott		3	-	-	-	91	89	
		2	-	-	2	106	70	2
8th Field Hosp		3	-	-	-	98	177	0
Other		9	2	-	-	80	236	1
Hon Tre		1	-	-	-	50	unk	3
Dong Ba Thin	(CP03)	5	5	-	-	42	0	5
Cam Ranh	(CP12)	21	1	1	-	191	1546	1
Phan Rang	(BN88)	-	-	-	-	-	-	4*
Phan Thiet	(AN81)	-	-	-	-	-	-	5
III Corps Area								
Song Be	(YU21)	-	-	-	-	-	-	4
Tay Ninh	(XT25)	2	-	-	-	308	263	3
Phouc Vinh	(XT05)	3	2	-	-	70	50	3
Dau Tieng	(XT55)	-	-	-	-	-	-	4
Ben Cat	(XT84)	2	-	-	-	128	unk	-
Lai Khe	(XT73)	1	-	1	-	178	0	6
Cu Chi	(XT72)	5	-	-	-	110	905	-
Phu Loi	(XT82)	4	-	-	-	303	430	2
Di An	(XT91)	8	-	-	-	254	546	-
Bien Hoa	(YT01)	9	-	-	-	157	1841	0

Location		Number of Wells Drilled Total	Dry	Test	Salt	Average Depth (ft)	Total Yield (GPM)	Wells Proposed
Long Binh	(YT11)	27*	4	-	-	167	2305	12*
Xuan Loc	(YT41)	3	-	-	-	98	130	-
Cortenay	(YT40)	2	1	-	-	127	30	4
Saigon		2	-	-	-	155	400	1
Nhon Trach	(YT00)	-	-	-	-	-	-	4
Nha Be	(XS99)	-	-	-	-	-	-	1
Binh Ba	(YS48)	-	-	-	-	-	-	1
Phu My	(YS28)	-	-	-	-	-	-	4
Baria	(YS46)	-	-	-	-	-	-	4
Vung Tau	(YS35)	13*	1	-	-	69	301	13*
Long Thanh	(YS20)*	7	-	-	-	161	965	0
Cat Lo		1	-	-	1	400	unk	1
Cat Lai		-	-	-	-	-	-	1
IV Corps Area								
Tuyen Nhon	(XS38)	-	-	-	-	-	-	3
My Tho	(XS55)	-	-	-	-	-	-	1
Dong Tam	(XS44)	-	-	-	-	-	-	1
Vinh Long	(XS31)	-	-	-	-	-	-	1
Can Tho	(WS81)	-	-	-	-	-	-	1
Soc Trang	(XR16)	-	-	-	-	-	-	1
TOTAL		191*	23	3	5		14,111	132*

*Indicates conflict in data between 1st Log Cmd & USAECV. The larger figure is shown in all conflicting cases.

(3) Proportion of Holes Drilled

The data obtained from "Water Well Production Program" prepared by 1st Logistical Command indicated that the following organizations were engaged in well drilling:

Organization	No. of Wells
Peril-Triumph Inc.	62
Roscoe-Moss Co.	86
Sea Bees (USNMCB)	10
US Army teams	14
Unknown	14
TOTAL	186

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APPENDIX 2 TO ANNEX A

SUMMARY OF RESPONSES TO INTERVIEWS

ON INDIVIDUAL TREATMENT

a. SAMPLING CONDUCTED

The personnel of each major unit visited were interviewed to determine the average water consumption rates, methods used for treatment by the individual soldier, and preferences of various individual containers.

The interview sample was carefully selected to eliminate individuals who spent most of their time on base camp duties. The reason for this selection was to reduce the bias toward consumption of water treated by large-scale methods.

Units whose mission required extensive use of heavy ground-mobile equipment (e.g., artillery and armor) were also eliminated from the survey, since it was found that in the majority of the cases treated water was available to the individuals from the 5-gallon containers carried on the vehicles. The primary sampling was therefore limited to the personnel of infantry, airborne, and combat engineer units.

An attempt was made to reduce the sample bias further by interviewing personnel in various geographical areas engaged in different operational missions.

The interviews were conducted mostly by the enlisted members of the team to reduce the tendency on the part of the interviewed men to give answers which they thought were desired rather than factual.

b. GENERAL

Total users interviewed 107

Number of individuals who never treated water in RVN. . . 14

Number of individuals who sometimes treated water 93

Number of individuals who never received training in water treatment 43

Number of individuals who received water treatment training 64

c. CONSUMPTION RESPONSE FREQUENCY BY AMOUNT

Number of quarts consumed daily	Number of Responses Water	Other liquids
0	0	3
1	6	44
2	32	21
3	26	21
4	31	4
5	6	1
6	3	0
6+	3	1
No record	0	12

Median Consumption Rate — 3.0 quarts water daily; 2.0 quarts other liquids daily

Average Consumption Rate — 3.2 quarts water daily; 1.6 quarts other liquids daily

d. TREATMENT

(1) Knowledge of three rules: "Drink only approved water, Do not contaminate, Do not waste."

Yes 71

No 33

No 3

(2) Knowledge of reason for waiting period

Yes 84

No 21

No record 2

(3) Supervision of treatment

"Self"	70
Aidman	14
NCO	4
No record	7

(4) Waiting period employed

More than 30 min.	48
16 to 30	40
10 to 15	9
Less than 10	4
No record	3

(5) Decontamination of canteen neck by inversion after adding tablets.

Yes	41
No	55
Sometimes	1
No Record	10

(6) Reading of the instructions on the label of iodine tablets

Yes	20
No	74
No record	3
Never used	10

(7) Number of tablets used per canteen

No. Tablets	Number of Responses		
	Muddy	Cloudy	Clear
0	0	0	1
1	3	6	39
2	43	53	45
3	19	7	
4	12	4	1
5	1	1	
5+	5		
No responses	16*	28*	13*
No. meaningful responses (excludes starred entry)	83	71	86
Median	2 tabs	2 tabs	2 tabs

(8) Knowledge of color of iodine tablets possessed

Gray 38

White 2

Brown 35

Gray or brown. 2

White or brown 1

Poor quality of tablets 38

Total meaningful answers 78

(9) Adequacy of water supply

Yes 89

No 12

Sometimes 6

e. CONTAINERS

(1) Individuals in possession of following canteens:

Standard plastic canteen only 55

Standard metal canteen only 1

Collapsible 2-qt canteen only 1

Plastic and metal 9

Plastic and collapsible 40

Plastic, metal, and collapsible 1

(2) Types of canteens used presently or in past:

Plastic only 12

Plastic and metal 44

Plastic and collapsible 19

Plastic, metal and collapsible. 32

(3) Breakdown of stated preference:

Plastic 50

Metal 2

Collapsible 31

Plastic and collapsible 11

No preference 1

Preference not meaningful
(never used more than one kind of canteen). 12

(4) Problems encoutered in use of various canteens:

Problem	Plastic	Metal	Collapsible
Loop breaking off	4		
Stripping of thread	21		
Inserts in caps lost	1**	1	
Corrosion of body		4	
Puncture of body			8
Cracking of body			1
Clogging of strainer			3*
TOTAL	26	5	12

* Most strainers were removed prior to use. This figure is not meaningful.

** Contradictory statement.

APPENDIX 3 TO ANNEX A

OBSERVED LARGE SCALE TREATMENT EQUIPMENT

a. SOURCE OF DATA

The data shown in the following tables were obtained from actual observation of equipment located at the various units visited. The great majority of units were conducting combat operations at the time of evaluation, so that operational methods and procedures were observed in realistic setting.

b. EQUIPMENT OBSERVED

	Observed	In operation
Water purification unit, base mounted, 3000-gph	8	7
Water purification unit, van type body mounted, 3000-gph	11	11
Water purification unit, van type body mounted, 1500-gph	28	17
Water purification unit, trailer mounted, 600-gph, complete	2	1
Water purification unit, trailer mounted, 600-gph, filter assembly only	1	-
Diatomite water purification Set No. 2, 15-gpm	3	3
Diatomite water purification Set No. 4. 50-gpm	4	4
SUBTOTAL standard units	57	43
Integral water purification plant EBARA-INFILCO, 9000-gph	1	-
Integral water purification plant EBARA-INFILCO, 3000-gph	2	-
Integral water purification plant EBARA-INFILCO, 600-gph	3	-
SUBTOTAL non-standard units	6	-
TOTAL water purification units	63	43

c. RAW WATER PUMPS

(1) Totals Observed

Electric Raw Water Pumps

Standard....................	43
Non-standard................	12
SUBTOTAL	55
Gasoline Raw Water Pumps........	23
TOTAL	78

(2) Average Seal Life of Standard Electric Raw Water Pumps

Average Seal Life	"Problems"	"No Problems"
0 to 1 months	7	
2 to 3 months	10	
4 to 6 months	8	
more than 6 months		18
SUBTOTAL	25	18
TOTAL PUMPS	43	

Percentage with seal problems = 58%

d. FILTER PUMPS

Average Seal Life	"Problems"	"No Problems"
0 to 1 months	9	
2 to 3 months	2	
4 to 6 months	13	
more than 6 months		29
SUBTOTAL	24*	29
TOTAL PUMPS	53*	

e. CHEMICAL SOLUTION FEEDER MAINTENANCE

Incorrect Oil (not OT-10)....................... 8

Pump bodies.................................. 7

Diaphragms...................................14

Fuses.. 6

Suction Heads................................ 3

Generally poor maintenance (multiple problems not included in above)............................ 4

f. POWER SOURCES

(1) Inventory of Sources

Units on external power....................16

Units on organic power:

Extra-capacity generators................. 3

Standard generators, authorized number.... 14

Standard generators, in excess of TO/E..... 3

SUBTOTAL 20

* One unit was observed without filter pumps - raw water pump was substituted because the filter pump had a burned-out motor.

Number of units with direct exchange policy of Erdlator generators with supporting unit......15

(2) Generator Life

Type	Average Life to Breakdown less than 1000 hrs	more than 1000 hrs
Gasoline		
Military standard air cooled, 10-KW	11	5
Hollingsworth, 3-KW		1
Hol-Gar (WK8 and WK9)		2
John Rainer		1
Hercules, 10-KW		2*
SUBTOTAL	11	11
Diesel		
15-KW (make unknown)		3
SUBTOTAL		3
TOTAL	11	14

g. DIATOMITE WATER PURIFICATION SETS

1st Cavalry Division	Type	Coagulation	Filtration	Backwash	Disinfection	Source
Bong Son	#2	+	+	+	+	Clear Stream
Two Bits	#2	+	+	-	+	Rice Paddy
LZ Pony	#2	+	+	-	+	Rice Paddy
5th Special Forces Gp	two-#4	+	+	+	+	Well
MACV-Cmpd, Nha Trang	#4	+	+	+	+	Well

* Indicated new generators, total running time less than 1000 hrs.

Camp Alpha, Tan Son Nhut #4	-	+	+	+	Well

h. WATER TREATMENT PROCEDURES

Of the 43 treatment units observed in operation, the following is the breakdown on procedures used by operators:

	Number	Percentate
Filtration	43	100%
Disinfection	43	100%
Coagulation	28	65%
Taste and Odor Control	14	33%

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APPENDIX 4 TO ANNEX A

PERSONNEL AND TRAINING

a. PERSONNEL AUTHORIZATIONS

(1) Source of Data

The sources of data for personnel authorizations are the modified TOE's submitted to USARV and approved at least on the local level. In cases where no modification was submitted, the basic TOE figures were used.

(2) Engineer Units Organic to Combat Elements

Unit	TOE/ MTOE	Personnel Authorized SGT E5	CPL E4	SP4 E4	PFC E3	PVT E2
1st Eng Bn	5-156E			7	7	7
4th Eng Bn	5-156E	1		5	5	5
8th Eng Bn	5-216T	1	5		5	5
15th Eng Bn	NR	1		5	5	5
65th Eng Bn	NR	1		5	5	5
87th Eng Co	NR		1	1	1	
173rd Eng Co	5-137F			5	3	
175th Eng Co	5-107T			2	3	
Co A, 326th Eng Bn	5-27F		2		2	2
919th Eng Co	NR	1		2	1	
TOTAL		5	8	32	37	29

NR = No Record

(3) Engineer Combat and Construction Battalions, USAECV (P)

Each engineer combat and construction battalion is authorized by the basic TOE 5-36D, E and 5-116D two water purification units, 1500-gph capacity manned by an operation team of one E4, one E3, and one E2.

Total number of personnel authorized for units in the command are as follows:

SP4 E4............................ 76

PFC E3............................ 76

PVT E2............................ 76

(4) Teams of 5-500C Series

(a) Units which submitted MTOE with changes from basic TOE 5-500C:

Unit	O-2	E-6	E-5	E-4	E-3	E-2
10th Eng Det (GF, GH)		1*	1*/1	6	2	1
28th Eng Det (GG)	1		1*	1*/4	3	2
29th Eng Det (GG)				1*/2	2	
TOTAL	1	1*	2*/1	2*/12	7	3

(b) Following teams showed no changes from basic TOE 5-500C:

Type	Number	E-5	E-4	E-3	E-2
Well drilling (GE)	7	7	7		
Water Purification (GE)	23		23*/23	23	23
Water Transport (GH)	2		2	10	4
TOTAL	32	7	23*/32	33	27

(5) Recapitulation of Personnel Connected with Water Finding, Treatment, and Transport:

Officers	O-2	1
NCO	E-6	1
	E-5	7
	E-4	33

* Indicates noncommissioned officer

Specialists	E-5	8
	E-4	152
PFC	E-3	153
PVT	E-2	153
TOTAL		490

b. OBSERVED PERSONNEL GRADE STRUCTURE AND TRAINING STATUS

(1) Sources of Data

The following summary of grade distribution of water supply personnel is based on interviews with personnel manning the observed military treatment units. Units were not necessarily in operation at the time of survey. The higher grades (E-5 and E-6) are water supply foremen in charge of overall operations. The total number of treatment plants in this category is 41.

(2) Summary of Data - Grade Structure

Grade		Number	Remarks
SSG	E-6	4	Only one with MOS 51N40
SGT	E-5	3	
SP4	E-4	51	
PFC	E-3	53	Four act as team chiefs
PVT	E-2	7	
	TOTAL	118	

(3) Summary of Data - Training Status

On-the-job training only............................ 43

Advanced individual training at Ft. Leonard Wood.... 75

Percent school trained...........................63.6%

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APPENDIX 5 TO ANNEX A

SOFT DRINK IMPORTATION

a. SOURCES OF DATA

To compare the data on consumption of liquids other than water obtained from the interviews of the individuals in various major units it was decided to obtain overall figures from the agencies charged with importation of canned and bottled drinks into RVN. The comparison of the two sets of figures could support the credibility of the subjective data obtained from interviews if the two sets showed reasonable agreement.

The Army and Air Force Exchange System, Vietnam Regional Exchange imports all soft drinks and beer from CONUS and a portion of fruit juices and milk to be sold in its retail outlets. The Vietnam Regional Commissary imports the other portion of fruit juices and milk used in commissaries and government messes. The data obtained from the Saigon Regional Exchange come from the EDP readouts maintained by the Requirements and Distribution Branch. The data from the commissary were obtained from their records.

b. SUMMARY OF DATA

	Quantity Imported	
	Reported	Rate Quarts/Day
AAFES - Vietnam Region		
Soft drinks	1.2 million cases/month	360,000
Beer	1.0 million cases/month	300,000
Juice	155,000 gal per month	20,667
Commissary System		
Juice, retail	71,500 gal per momth	9,500
Juice, govt mess	75,000 gal per month	10,000
SUBTOTAL		700,167

Milk, retail, AAFES	10,000 gal per month	1,333
Milk, commissary	15,500 gal per month	2,067
Milk, govt mess	16,000 gal per month	2,133
	SUBTOTAL	5,533
	GRAND TOTAL	705,700

c. CALCULATIONS

To arrive at an approximate per-capita figure of consumption rate it was necessary to estimate the number of consumers authorized the use of above facilities. In addition to approximately 430,000 US military patrons, there are numerous authorized civilian and allied military customers. However for the purposes of rough comparison a figure of 500,000 personnel was considered sufficiently close to the true figure. On this basis the daily consumption figures are found to be:

Total figure excluding milk: 1.40 quarts/cap/day

Total figure including milk: 1.41 quarts/cap/day

APPENDIX 6 TO ANNEX A

INVENTORY OF WATER TREATMENT FACILITIES

a. US ARMY OPERATED FACILITIES

(1) Codes for Equipment Encountered

A - Water Purification Unit, trailer mounted, 600-gph (FSN 4610-542-4024)

B - Integral Water Purification Plant, EBARA-INFILCO, 600-gph (Non-standard)

C - Water Purification Set, portable, 600-gph (FSN 4610-902-3106)

D - Diatomite Water Purification Set No. 2, 900-gph (FSN 4610-190-0297)

E - Water Purification Unit, van type body mounted, 1500-gph (FSN 4610-202-6925)

F - Water Purification Unit, van type body mounted, 3000-gph (FSN 4610-202-8701)

G - Water Purification Unit, base mounted, 3000-gph (FSN 4610-202-8700)

H - Diatomite Water Purification Set No. 4, 50-gpm (FSN 4610-190-0301)

(2) Sources of Data

The sources of data for the US Army operated facilities are the modified TOE's submitted to USARV and approved at least on the local level. Items appearing in the "additionally authorized" column came from TWX message from USARV to Department of the Army giving shipping instructions on Lightweight Water Purification Unit, 600-gph, (ENSURE).

(3) Engineer Units Organic to Combat Elements

		Equipment on Hand			Add. Auth	
Unit	MTOE	Code A	Code E	Other	No.	Code
1st Eng Bn	5-156E		7		4	A
4th Eng Bn	5-156E		5		4	A
8th Eng Bn	5-216T			5-D	0	-
15th Eng Bn	NR		5		4	A
65th Eng Bn	NR		5	2-B*	4	A
87th Eng Co	NR		1		2	A
173rd Eng Co	5-137F	1	2		2	A
					1	C
175th Eng Co	5-107T		1		2	A
Co A, 326th Eng Bn	5-27F	2			2	A
919th Eng Co	NR		2		0	-
TOTAL		3	28	5-D 2-B*	24 1	A C

NOTES: NR=No Record; *=Not in operable condition

(4) Engineer Units Under Engineer Command, USAEC-V (P) and 1st Logistical Command

			Equipment, total	
Type of Unit	MTOE	No. units	O/H	Ordered
Eng, Bn, Combat, Army	5-36D	7	14-E	
Eng, Bn, Combat, Army	5-36E	4	8-E	
Eng, Bn, Construction	5-116D	8	16-E	
Team GF (Water Purif)	5-500C	24	24-F	
Team GG (Water Purif)	5-500C	2	8-F	
USAEC-V, unit unit unspecified				13-A

Total 600-gph Code A		13-A
Total 1500-gph Code E	38-E	
Total 3000-gph Code F	32-F	

(5) Recapitulation of Water Purification Equipment

Code	Name	Number O/H	Number Ordered
A	Water Purification Unit trailer mounted, 600-gph	3	37
B	Integral Water Purification Plant, EBARA, 600-gph	2	
C	Water Purification set, Portable, 600-gph	1*	
D	Diatomite Water Purification Set No. 2, 900-gph	5	
E	Water Purification Unit, van body mounted 1500-gph	66	
F	Water Purification Unit, van body mounted, 3000-gph	32	
	TOTAL	109	37

b. CONTRACTOR OPERATED FACILITIES

(1) Sources of Data

USARV Regulation 420-2 "Water Supply Systems - Responsibilities, Procedures and Reports" dated 23 October 1965 requires major subordinate commanders to submit monthly water supply status report to the Engineer, USARV. This report encompasses data on plant location, water source, responsibility for operation and maintenance, type of equipment, and other pertinent data. Compliance with the regulation is incomplete except at some logistical units having contractor-operated water treatment facilities. The monthly reports were used only to extract the pertinent operational data on civilian-operated plants. It is realized that some figures reported might be only rough estimates, especially in the case of monthly water production figures, since adequate completion of water distribution forms was not made.

The data obtained from the above reports were compared with the data contained in "Water Well Production Program", a report published by Pacific Architects and Engineers, Inc. for 1st Logistical Command.

* Indicates authorized, not on hand.

A number of entries conflict. In such cases the conflict was resolved by taking PA&E data and an appropriate notation was made.

(2) Summary of Data

(a) Summary of Data

(a) Sources of Water

Ground water	77
Surface water	20
City water	6
Trucks	3
TOTAL	106

(b) Types of Equipment in use

	Potable	Non-potable
Erdlator-type equipment		
3000-gph capacity	35	
1500-gph capacity	11	
600-gph capacity	4	
Diatomite Filters		
A-C-Lo Prest, 252-gpm capacity	1	
Set No. 4, 50-gpm capacity	18	1
Set No. 2, 15-gpm capacity	4	
Sand Filters	2	1
Hypochlorinators, only	17	8
None		4
TOTAL	92	14
	106	

(c) Locations of Facilities and Approximate Production Figures

Location	No. of Facilities Potable	No. of Facilities Non-potable	Estimated Monthly Production 1000's gal Potable	Estimated Monthly Production 1000's gal Non-Potable	Rated Capacity gallons/hour Potable	Rated Capacity gallons/hour Non-potable
Phu Bai (YD92)	1**	1	772	5552*	600	6,000
Da Nang (BT18)	4**		3309		7500	
Quan Ngai (BS77)	1**		856*		600	
Pleiku (AR85)	3**	2**	3929*	9646	8100	72,000+
An Khe (BR45)	1	1	NR	NR	6000	NR
Qui Nhon (CR12)	11	1	9666*	1110	19200	3,000
Tuy Hoa (CQ24)	1**		450		UNK	
Ban Me Thuot (AQ10)	2		1281		6000	
Khanh Duong (BP38)	NR		NR		NR	
Nha Trang (CP05)	5		8748*		18000	
Cam Ranh (CP02)	5	4	10708*	15070*	39240	21,180
Phan Thiet (AN11)	1		374		3000	
Lai Khe (XT84)		1**		6160		12,000
Phuoc Vinh (XT95)	1**		1500		3000	
Cu Chi (XT62)	3		3518*		9000	
Di An (XT81)	1		3061		4740	
Bien Hoa (YT02)	3	1**	1867	5214*	15000	6,000
Long Binh (TY01)	5**	1**	9685	UNK	21500	UNK
Tay Ninh (XT26)	1**		165		3000	
Saigon	14**	5**	33649	12401	58800	UNK
Long Thanh (YS29)	2		2719		9480	
Dong Tam (XS45)	1		980		3000	
My Tho (XS45)	1		290		900	
Vung Tau (YS45)	4	1**	13242	4650	24120	UNK
Vinh Long (XS03)	2	2	3109	3132	9000	UNK
Can Tho (WS80)	2		1555		3000	
Soc Trang (XR18)	1	1	5961*	54[illegible]	9000	
TOTAL	75	21	121394	68389	281900	

NOTES: *Estimated monthly production higher than rated capacity of purification units
**Conflict between monthly water status report and PA&E water well production program

(d) Contractor-Operated Ice Plants

Location	Unit Capacity Tons/day	No. of Units	Total Capacity Tons/day
AN KHE	15.0	4	60
BEAR CAT	15.0	1	15
BIEN HOA	15.0	1	15
CAM RANH	15.0	2	30
CU CHI	15.0	2	30
DALAT	3.6	1	3.6
DI AN	3.6	5	18
DONG TAM	15.0	1	15
LAI KHE	3.6	4	14.4
LONG BINH	15.0	2	30
NHA TRANG	15.0	3	45
PHAN RANG	15.0	2	30
PHOUC VINH	3.6	4	14.4
PLEIKU	15.0	3	45
QUI NHON	15.0	3	45
TAY NINH	15.0	1	15
TUY HOA	15.0	2	30
VUNG TAU	15.0	1	15
XUAN LOC	15.0	1	15
TOTAL			495.4

c. SUMMARY OF EQUIPMENT

Treatment Unit	Military Operated On hand	Military Operated Proposed	Contractor Operated In Operation	Contractor Operated Not in Operation
Erdlator type				
600-gph	5	38	4	
1500-gph	66		11	
3000-gph	32		35	2*
9000-gph				1*
Diatomite				
900-gph	5		4	
3000-gph			18	
15000-gph			1	
Sand Filters			3	
Hypochlorinators			25	
TOTAL	108	38	101	3*
GRAND TOTAL			209	41*

* Incomplete entries based only on observed units

d. RATED CAPACITY OF UNITS ON HAND

Type Treatment Unit	No.	Total Rated Capacity Gal/Min	Thousands gal/hr	Thousands gal/day
Erdlator Type				
600-gph	9		5.4	108*
1500-gph	77		5.5	2310*
3000-gph	67		201.0	4020*
9000-gph	1		9.0	180*
Diatomite				
900-gph	9		8.1	162*
3000-gph	18		54.0	1080*
252-gpm	1	252		302*
Sand Filters	3	72		104
Hypochlorinators	25	1480		1537
TOTAL				9803

* Based on 20-hr production day
The US Army equipment on hand, both military and civilian operated has a total rated capacity of 9.8 million gallons per day.

APPENDIX 7 TO ANNEX A

WATER CONTAINERS AND STORAGE

a. MOBILE CONTAINERS

(1) Source of Data

The source of data for water containers authorized by TOE, MTOE, and actually on hand was the USARV (AR 711-5) Unit Equipment Status Command Summary, which was current as of 31 December 1966.

(2) Summary of Data

(a) Water trailers (Note: For the purpose of this tabulation, older 250-gallon metal water trailers were not distinguished from the present standard 400-gallon fiberglass water trailers. The relative proportion of the two types is unknown.)

Unit	Total water trailers		
	TO/E	MTO/E	O/H
1st Cavalry Division (AM)	52	67	52
1st Infantry Division	79	79	82
1st Brigade, 101st Airborne Division	19	19	18
18th Engineer Brigade (USAECV)	99	100	100
23rd Artillery Group	16	17	15
34th General Support Group	14	15	12
18th Military Police Brigade	25	25	25
97th Artillery Group	8	8	7
196th Light Infantry Brigade	38	40	39
525th Military Intelligence Group	6	7	4
1st Aviation Brigade	54	55	49
Hq, USARV, Special Troops	3	3	4
1st Signal Brigade	58	59	26

I Field Force V	50	57	48
11th Armored Cavalry Regiment	22	22	34
173rd Airborne Brigade	34	34	36
509th RRU Group	9	11	7
1st Logistical Command	8	8	6
II Field Force V	15	15	27
4th Infantry Division	121	156	157
25th Infantry Division	106	128	120
Headquarters Area Command, Saigon	20	20	20
9th Infantry Division	71	71	71
Saigon Support Command (Depot)	87	92	85
Cam Ranh Bay Support Command (Depot)	85	89	8
4th Transportation Corps Command	9	10	8
Quy Nhon Support Command (Depot)	52	52	44
199th Light Infantry Brigade	24	8	12
Unassigned Units	7	7	11
TOTAL	1168	1266	1187

(b) 1000-gallon Water Tank Trucks

Unit	Total 1000-gallon trucks TO/E	MTO/E	O/H
1st Cavalry Division	1*	1*	1*
1st Brigade, 101st Airborne Division	2	2	2
173rd Airborne Brigade	2	2	1

* 900-gallon water tank truck, 2½-ton

Qui Nhon Support Command**	5*	5*	5*
Cam Ranh Bay Support Command**	5*	5*	5*

b. STORAGE AT WATER POINTS (BASE CAMPS)

(1) Source of Data

The water production at larger base camps was normally found to be the responsibility of the 1st Logistical Command. To estimate the amount of storage availabe the data were extracted from the 1st Logistical Command report "Well Production Program" prepared by PA&E which included all water points belonging to that command. No data are available on storage at treatment sites operated by the organic engineer units. These units rarely possessed storage facilities in excess to their normal TOE.

(2) Summary of Data

Number of various storage containers arranged by size and material:

	Rubber		Steel		Concrete	
Capacity	Elev	Not Elev	Elev	Not Elev	Elev	Not Elev
less than 500		1				
500-1499		4	4		4	2
1500-2999	4	96	6			4
3000-4999	2	113	16		6	10
5000-9999	2		30	1	8	5
10000-14999		2	9		12	
15000-24999	1	1	1		2	1
25,000 +			15		5	10
TOTAL	9	217	85	1	38	32

* Tank trucks assigned to TOE 5-500C Team GH

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APPENDIX 8 TO ANNEX A

DISTRIBUTION OF WATER

a. GROUND TRANSPORTATION

(1) Source of Data

To obtain an idea of types of vehicles used in bulk transportation of water a nine-day inventory of vehicles and containers was kept at one of the large infantry division base camps (approximately 8000 men). The data represents non-potable consumption from an efficiently operated water point.

(2) Equipment Used in Water Pickup

(a) Standard liquid bulk transporters

Type	No. of Trips	Water Hauled, Gal 9-day Period	Gal/Day
5-ton, tank, 1800 gallon	19	34,200	3,800
$2\frac{1}{2}$-ton, tank, 1200 gallon	25	30,000	3,330
Trailer, 400 gallon	129	51,600	5,730
TOTAL			12,860

(b) TOE tactical vehicles with semi-permanently mounted containers.

Vehicle	Containers	No. of trips	Water Hauled, Gal 9-day Period	Gal/Day
5-ton truck	Cube, 1200 gal	13	15,600	1,730
	3 fuel cells, 250 gal ea	1	750	80
$2\frac{1}{2}$-ton truck	5 napalm containers 250 gal ea	28	35,000	3,890
	3 napalm containers 250 gal ea	165	123,750	13,750
	Cube, 1000 gal	2	2,000	220
3/4-ton truck	3 napalm containers	45	33,750	3,750
	2 napalm containers	2	1,000	110
TOTAL				23,530

(2) Data and Calculations

The average number of resupply missions during the first month of the operation for both companies amounted to 36 per day. Since water treatment units were set up in the forward support areas the average turn-around time amounted to 35 minutes during phases I and II of the operation, but increased to 45 minutes when the operation moved into phase III, since some forward support areas were closed and missions had to be flown from base camps further removed from operating areas.

Both 250-gallon and 400-gallon trailers were air lifted to forward areas but the evaluators could not determine the proportions of each. For the purposes of calculation it will be assumed that all trailers were of the 400-gallon size, which results in more conservative cost figures.

To determine the cost of transportation per gallon of water delivered it is necessary to estimate the cost per flying hour for CH-47 helicopters. The only figure available in literature comes from an American Power Jet study and amounts to $451.81. This figure includes cost of parts, labor, and crew salaries. How realistic this figure is in context of operations in Vietnam is unknown.

Total amount of water delivered per day

$$= 400 \frac{\text{gallons}}{\text{trailer}} \times 36 \frac{\text{trailers}}{\text{day}}$$

$$= 14{,}400 \text{ gallons/day}$$

Total flying time per day =

$$36 \frac{\text{flights}}{\text{day}} \times 35 \frac{\text{minutes}}{\text{flight}} \times \frac{1 \text{ hour}}{60 \text{ minutes}}$$

$$= 21 \text{ hours/day}$$

Total estimeted cost per gallon

$$= \frac{21 \text{ hours/day} \times \$451.81/\text{hr}}{14{,}400 \text{ gal/day}}$$

$$= 0.659 \text{ \$/gallon} = 66¢/\text{gallon}$$

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ANNEX B

PROPOSED CHANGES IN WATER SUPPLY ORGANIZATIONS

1. BACKGROUND

As noted in section II, paragraph B 3c, the evaluation report indicates inadequacies in grade structure of water supply operators. Additionally, section II, paragraph B 3e contains a recommendation to realign the responsibilities for water supply within the divisional units. Annex B outlines the proposed changes in water supply organizations at division and 1st Logistical Command levels. The standards of grade authorizations in AR 611-201 should be changed to reconcile necessary mission requirements and responsibilities.

2. DIVISIONS AND SEPARATE BRIGADES

a. Infantry Division

(1) In TOE 5-156E, Headquarters and Headquarters Company, Engineer Battalion, Infantry Division the following personnel together with the necessary equipment should be deleted from the Supply Section:

1	SGT	E-5	Water Supply Foreman	51N40
5	SP4	E-4	Senior Water Supply Specialist	51N20
5	PFC	E-3	Water Supply Specialist	51N20
5	PVT	E-2	Water Supply Helper	51N10

(2) In TOE 10-7E, Supply and Service Company, Supply and Transportation Battalion, Infantry Division, Water Supply Section should be added. This section should include the following personnel:

1	SFC	E-7	Section Chief	51N40
1	SSG	E-6	Production Supervisor	51N40
5	SGT	E-5	Water Supply Foreman	51N40
3	SP4	E-4	Senior Water Supply Specialist	51N20
4	PFC	E-3	Water Supply Specialist	51N20
3	PVT	E-2	Water Supply Helper	51A10

The above table represents the summary of personnel necessary to operate five 1500-gph erdlators. Each operating team is to consist of one water supply foreman and an appropriate mixture of specialists and

helpers. The production supervisor must be highly skilled in equipment maintenance and supply procedures. In addition to water purification equipment this section should be authorized all other ancillary equipment necessary to support its mission.

(3) When units are authorized additional water purification equipment under MTOE, three-man teams each consisting of a water supply foreman, a senior water supply specialist, and a water supply specialist, should be added to augment the water supply section.

b. Airmobile Division

(1) In TOE 5-216T, Headquarters and Headquarters Company, Engineer Battalion, Airmobile Division, the following personnel together with the necessary equipment should be deleted from the supply section:

1	SGT	E5	Water Supply Foreman	51N40
5	CPL	E4	Water Supply Team Chief	51N40
5	PFC	E3	Water Supply Specialist	51N20
5	PVT	E3	Water Supply Helper	51A10

(2) In TOE 29-97T, Supply Company, Supply Battalion, Airmobile Division, a water supply section should be added to the main support platoon. The personnel of this section should be identical to the personnel recommended under paragraph 2 a (2), annex B.

c. Separate Airborne Brigade

The TOE 5-13F, Engineer Company, Separate Airborne Brigade, should be changed to strengthen the grade structure.

The following personnel should be added:

1	SGT	E5	Water Supply Foreman	51N4P
1	SP4	E4	Senior Water Supply Specialist	51N2P

The following should be deleted:

1	CPL	E4	Water Supply Team Chief	51N4P

and the following should remain unchanged:

1	PFC	E3	Water Supply Specialist	51N2P

d. Separate Light Infantry Brigade

The TOE 5-10T, Engineer Company, Light Infantry Brigade, should be changed to strengthen the grade structure.

The following changes are recommended:

Add:	1	SGT E5 Water Supply Foreman	51N40
Delete:	1	CPL E4 Water Supply Team Chief	51N40
Retain:	1	SP4 E4 Senior Water Supply Specialist	51N20
	1	PFC E3 Water Supply Specialist	51N20

3. TEAMS OF TOE 5-500 SERIES

a. Small Water Purification Team

The water purification team GC* designed to operate one 3000-gph Erdlator should be composed of the following personnel:

1	SGT E5 Water Supply Foreman	51N40
1	SP4 E4 Senior Water Supply Specialist	51N20
1	PFC E3 Water Supply Specialist	51N20
1	PVT E2 Water Supply Helper	51A10

b. Large Water Purification Team GD* designed to operate four 3000-gph Erdlators should be changed in composition. It is recommended that the water supply engineer officer (MOS 4940, 1LT) position be deleted in this size team. The new composition of the team should be:

1	SFC E7 Water Supply Supervisor (Team Chief)	51N40
1	SSG E6 Production Supervisor	51N40
4	SGT E5 Water Supply Foreman	51N40
2	SP4 E4 Senior Water Supply Specialist	51N20
2	PFC E3 Water Supply Specialist	51N20

* Teams GC and GD, TOE 5-500E, are still designated as teams GF and GG, respectively, TOE 5-500C in RVN.

2 PVT E2 Water Supply Helper 51A10

c. Headquarters Team (AB)

It is recommended that more use be made of existing headquarters cellular teams. To supervise various water purification and water transport teams assigned to the 1st Logistical Command, it is recommended that team AB, separate platoon headquarters, be used. The platoon commander should be qualified as water supply engineer officer (MOS 494C).

4. WELL DRILLING

a. Well drilling was assigned to the Construction Agency, US Army Engineer Command Vietnam, as part of base development and was accomplished by a combination of contractor and troop effort. The contractor effort was completed ahead of schedule because of experienced well equipped crews and experienced supervision. The troop effort, however, had to overcome many problems before becoming reasonably effective.

b. Problems encountered in Army troop well drilling:

(1) Inadequate knowledge in drilling and developing of wells both on the part of well drilling teams, supporting personnel, and supervisors.

(2) Improper maintenance of drill rig and tools.

(3) Shortage of necessary supplies and repair parts.

(4) Shortage of necessary equipment to properly complete well.

(5) Insufficient number of personnel to properly operate drill rig.

(6) Inflexibility of the drill rig to meet varying Vietnam conditions.

c. Recommended solutions:

(1) That a separate Army well drilling unit be formed and that this unit have a TOE that includes supervisory, supply, and maintenance personnel.

(2) That career opportunities for well drillers not be limited to pay grade E-4.

(3) That the training program for well drillers in CONUS be re-evaluated and that necessary action be taken to improve the course.

(4) That in the future a standard, more versatile, more complete well drilling rig be purchased for use by the Army. For Vietnam a rotary rig is recommended. Also, a welder and air compressor should be part of the TOE.

(5) That only standard TM and FSN equipment and supplies be used in the well drilling program to facilitate obtaining repair parts and drilling materiels.

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(U) ANNEX C

SETTING OF THE EVALUATION

1. ENVIRONMENT

The Republic of Vietnam (RVN) occupies a crescent-shaped area of about 67,000 square miles on the southeastern edge of the Indochina Peninsula. Although only 45 miles wide at the 17th parallel, its demilitarized northern border with North Vietnam, it has a seacoast of 1,500 miles on the South China Sea and Gulf of Siam, and western borders with Laos and Cambodia of about 900 miles. The land borders are poorly defined and drawn through difficult and inaccessible terrain.

a. Terrain

There are four distinct geographical regions: The highlands located in the north and central portion, the plateaus of the central highlands, the coastal plain, and the Mekong Delta in the south. (See figure C-1.)

The northern two-thirds of the RVN is dominated by a chain of broken mountains and rugged hills extending in a northwest-southeast direction and terminating on the northern edge of the delta plain about 50 miles north of Saigon, the capital. The area is characterized by steep slopes, sharp crests, narrow valleys, and dense vegetation. It is sparsely populated, mainly by primitive and nomadic tribes, and it contains few roads or trails.

The central highlands adjacent to the Laos-Cambodia border contain extensive plateau areas. Here, the mountains give way to more gently rolling terrain. The northern plateau is covered by almost impenetrable tropical forests and jungles, which often have two dense overhead layers of foliage at heights of about 40 and 125 feet. The southern portion is typical savannah country, with large open expanses covered by tropical grasses and open forests. This region is more heavily populated than the northern highlands and has more roads and trails.

The coastal plain, varying from 10 to 25 miles in width, extends from the 17th parallel to the Mekong Delta. At several places mountain spurs jut out to the sea, cutting the plain into a series of compartments roughly at Mui Dinh, Mui Ke Ga, Quang Ngai, Da Nang, and Hue, north of which the spurs become more frequent. The area is characterized by sandy beaches and dunes, backed up by rice fields, fertile areas, and marshes extending to the mountains. It contains many small cities.

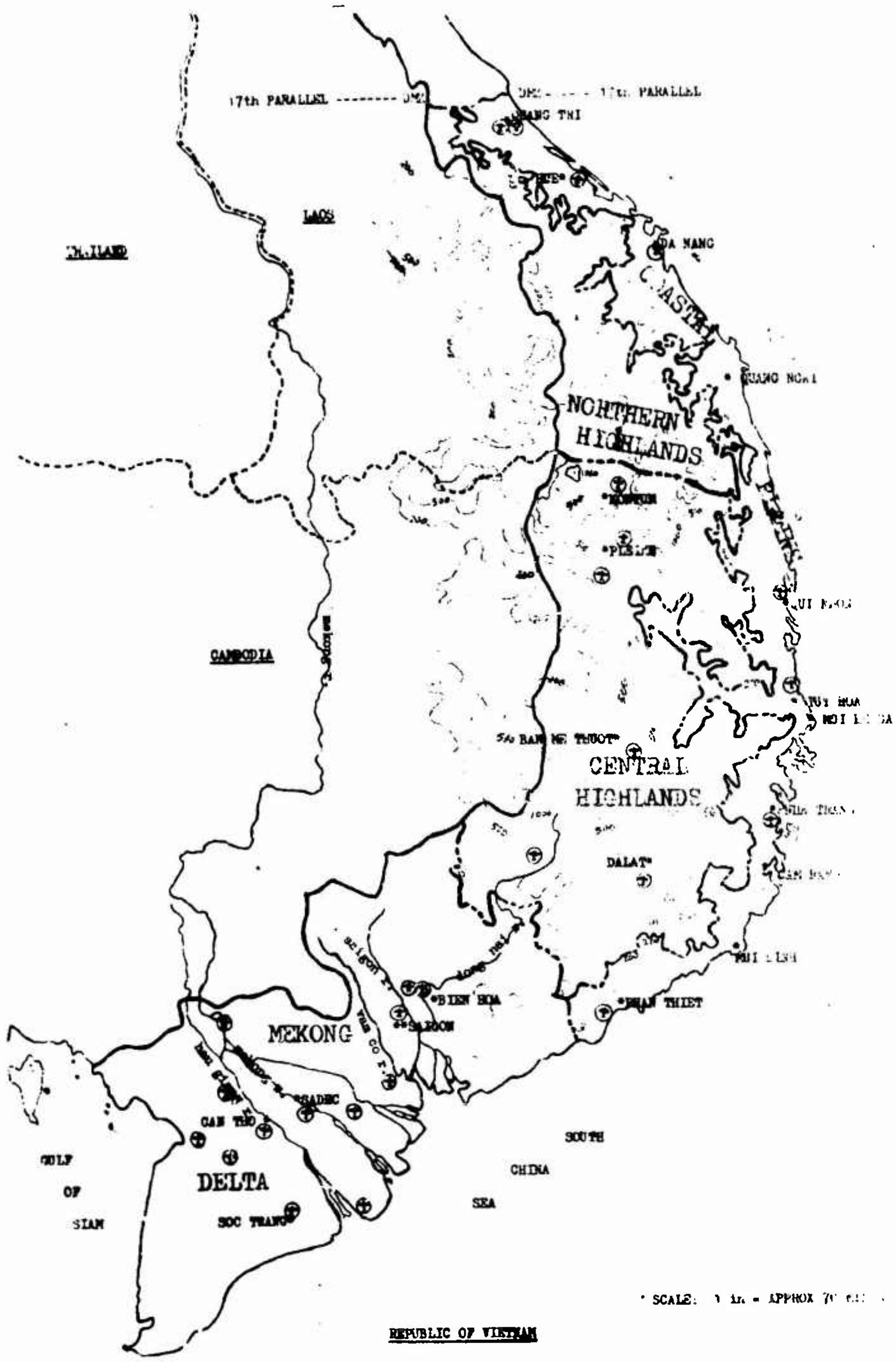

FIGURE C-1. Geographical regions, RVN.

The southern third of the country is part of the large delta plain formed by the rivers Hau Giang, Mekong, Vam Co, Saigon, and Dong Nai. The Hau Giang flows directly to the South China Sea. The huge Mekong splits into four branches and the Vam Co and Dong Nai enter the Saigon before reaching the sea. In addition to these major tributaries, the area is cut by a number of smaller streams and a dense network of canals. The plain is quite flat, with few points exceeding an elevation of 20 feet above sea level. It is a very fertile area with more than 9,000 square miles under rice cultivation. Drainage is effected chiefly by tidal action, with the difference between ebb and flood as much as 10 feet in some areas. The southernmost tip of the delta, known as the Can Mau Peninsula, is covered with dense jungles, and mangrove swamps stand at the shoreline and on river estuaries. The eastern portion of the delta plain is heavily forested. The Plain of Reeds, a large marshy area covered with tall reeds and scrub trees, is located in the center of the delta region adjacent to the Cambodian border. During the rainy season, a major portion of the entire area is inundated.

b. Climate and Weather

The climate is hot and humid, subtropical in the north and tropical in the south where the monthly mean temperature is about 80 degrees Fahrenheit. The annual rainfall is heavy in most regions and torrential in many. It is heaviest at Hue which has an annual average of 128 inches. The low of 28 inches at Mui Dinh, a small cape on the eastern coast some 62 miles south of Nha Trang, results from the presence of hills in the area. At Saigon, rainfall averages 80 inches annually. (See figure C-2.)

Seasonal alternation of monsoon winds profoundly influences the weather throughout the year, although geographical features alter patterns locally. The winter monsoon blows generally from the northeast from early November to March and often brings floods to the northern portion of the RVN. This is the period of the dry season in the delta, which usually lasts from December through March. The winds begin to shift in March and, with the exception of the coastal plain, high temperature and humidity pervail in all of the RVN from April to June. The summer monsoon blows generally from the southwest from June to late August or early September, bringing to the delta region heavy and frequent rains, high humidity, tropical temperatures, and maximum cloudiness. Mountains cause clouds to pile up and deposit moisture before the clouds reach the coastal plain or the northern highlands, which areas are dry during this period. In September the winds begin to shift again and the coastal plain receives its maximum amount of rain and cloud cover, including severe tropical storms and typhoons.

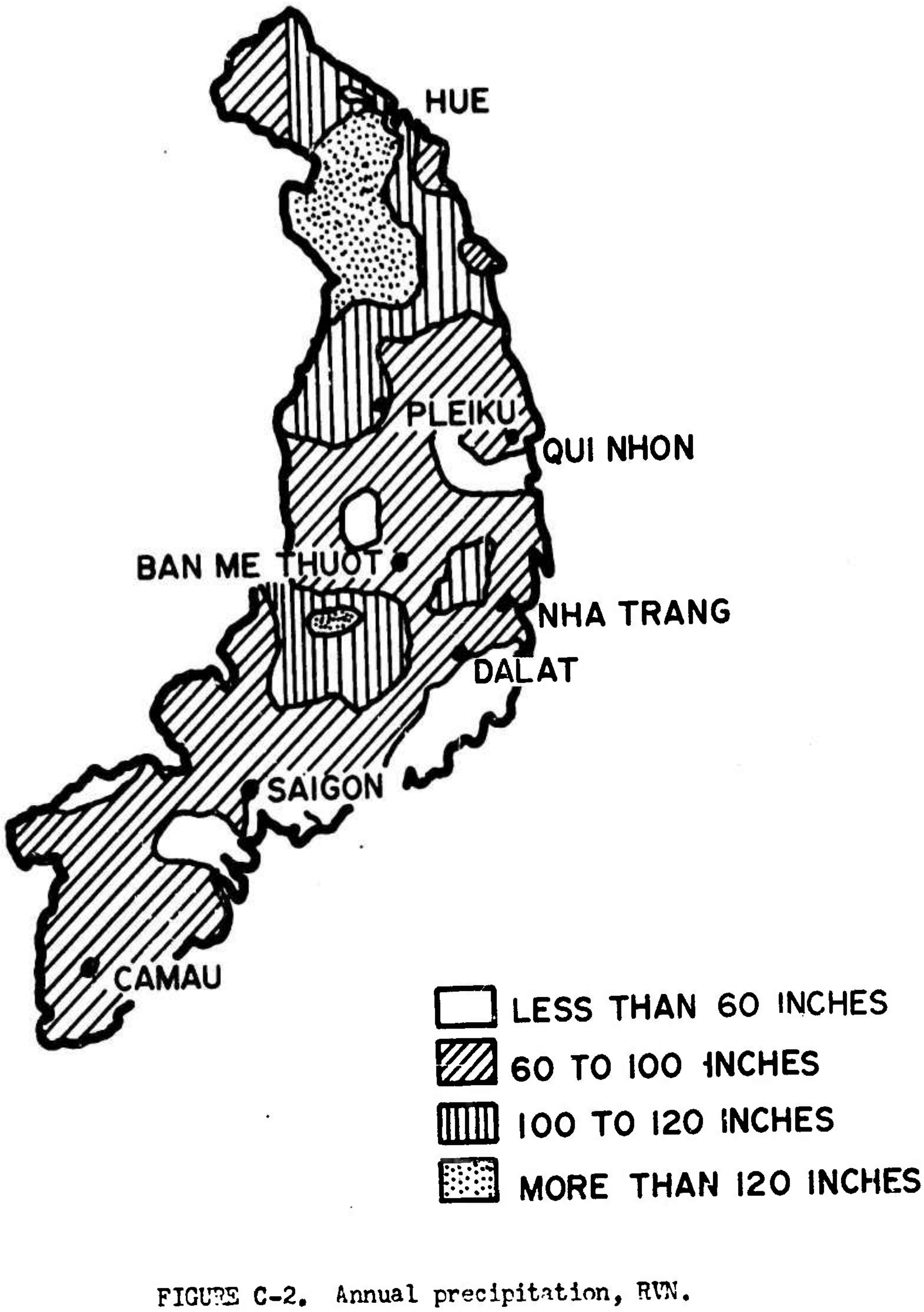

FIGURE C-2. Annual precipitation, RVN.

(U) ANNEX D

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13. ABSTRACT

This project was conducted to evaluate water supply and procedures, to determine water requirements and sources and the adequacy of containers and storage facilities, and to evaluate the purification and delivery means to meet the requirements of supporting US Army troops in the Republic of Vietnam (RVN).

Drinking water for troops is not a major problem in Vietnam even though certain areas require improvement. Standard treatment equipment is considered adequate when maintained properly. Medical and engineer personnel need improved test equipment in order to perform the necessary test and evaluations of new raw water sources.

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